

SPECIFICATION

Docket No. 0291H-34638

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that I, Daniel R. Joseph, a citizen of the United States of America, residing in the City of Weatherford, Texas, have invented new and useful improvements in a

IMPROVED METHOD AND APPARATUS FOR AUTOMATIC CONTROL OF CAGE SIZE IN AN EXTRUDED FILM PRODUCTION LINE.

of which the following is a specification:

"EXPRESS MAIL" NO. EL555424878US

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By:

James E. Walther

Date of Deposit:

4/9/01

BACKGROUND OF THE INVENTION

1. Claim of Priority:

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/195,379, filed 7 April 2000, entitled "Method and Apparatus for Automatic Control of Cage Size in an Extruded Film Production Line." This provisional application is incorporated herein as if fully set forth.

2. Field of the Invention:

This invention relates generally to blown film extrusion lines, and specifically to operations of the inlet and outlet blowers of blown film systems.

3. Description of the Prior Art:

Blown film extrusion lines are used to manufacture plastic bags and plastic sheets. A molten tube of plastic is extruded from an annular die, and then stretched and expanded to a larger diameter and a reduced radial thickness by the action of overhead nip rollers and internal air pressure. Typically, air is entrained by one or more blowers to provide a cooling medium which absorbs heat from the molten material and speeds up the change in state from a molten material back to a solid material. Additionally, blowers are used to provide air pressure which is utilized to control the size and thickness of the film tube. One type of blown film extrusion line utilizes an air flow on the exterior surface of the film tube in order to absorb heat. A different, and more modern, type of blown film extrusion line utilizes both an external flow of cooling air and an internal flow of cooling air in order to cool and size the film tube.

As stated above, blowers are utilized to provide air to the interior of the film tube. Typically, a supply blower is provided in order to supply air to the interior of the film tube, and an exhaust blower is provided in order to exhaust air from the interior of the film tube. Typically, the supply blower and exhaust blower

are under electrical control during production operations. However, during startup of the extrusion process, in the prior art, a great deal of human intervention is required in order to establish the bubble. Typically, a human operator will first control the supply blower until the extruded film tube is closed at its upper end by engagement with the overhead nip rollers. Then, the exhaust blowers utilized to remove air in order to prevent expansion and eventual breaking of the extruded film tube. A balance between the supply blower and the exhaust blower must be obtained in order to allow for continuous production of the extruded film tube. The startup of an extruded film is a relatively difficult operation to perform, and generally requires a relatively highly-skilled employee to oversee or perform the startup operations.

SUMMARY OF THE INVENTION

It is one objective of the present invention to provide an improved control system for use in a blown film extrusion line which provides automatic control over the position of a sizing cage which is the part of the blown film extrusion line which helps to establish the diameter or size of the blown film product. The present invention integrates easily with a bubble control system to ensure bubble stability during all size changes.

It is an additional objective of the present invention to provide a control system for automatically controlling the size of a cage in a blown film extrusion line without requiring the utilization of any additional mechanical, electrical or other sensor mechanisms as is common in prior art approaches to controlling cage size. Accordingly, it is easily retrofit into existing blow film lines which have a motorized cage. This retrofitting can be accomplished without utilizing any encoders that are typically utilized in prior art cage control systems.

It is another objective of the present invention to provide a cage controller which is responsive to operator input for a target size for the blown film product, which operates thereafter without requiring operator attention, moving the cage radially inward or outward relative to the blown film tube in order to obtain the size setting or goal established by the operator.

In accordance with the preferred embodiment of the present invention, the cage control system utilizes sensors which have other functions or purposes within the blown film extrusion system. For example, lay flat sensors are utilized to provide measurement of the diameter of the extruded tube after it has cooled, thus providing an indication of the "lay flat" dimension of the product. Additionally, one or more ultrasonic sensors utilized to control the cooling of the bubble are utilized to determine the location of the cage in order to allow for intelligent control thereof. Preferably, but not necessarily, the lay flat sensors

are located in upward position several feet preferably vertically displaced from the IBC sensor which is utilized to control the sizing and cooling of the molten tube.

In accordance with the preferred embodiment of the present invention, the control over the location of the cage is accomplished utilizing two distinct modes of control operation. The first mode of operation is considered a "forecast" mode of operation in which the operator input is received and relatively "gross" movement of the cage is obtained (preferably in discrete predefined steps of increase or decrease) in order to move the cage either radially inward or radially outward in order to size the bubble in accordance with the operator's selected value. Once this relatively gross resizing of the cage occurs, the forecasting mode is terminated and a "contact" mode of operation is entered in which finer control is obtained. In accordance with the preferred embodiment of the present invention, the "contact" mode of operation is characterized by the extruded film tube making physical contact with a roller assembly which is carried by the cage and which is utilized to physically engage the tube as it passes upward through the production equipment. One advantage that can be obtained utilizing the "contact" mode of operation is the slight over-sizing or slight undersizing of the tube relative to the cage. This will determine the amount of physical contact that the roller assemblies make with the extruded film tube. Certain types of relatively soft material may be produced more effectively with a lesser amount of contact. Accordingly, the operator is allowed to select an amount of "underage" of such contact within a preselected range. Conversely, if the material is relatively hard or stiff material, a greater amount of contact be desirable in order to increase the amount of production which can be obtained through the production line per hour. Accordingly, a certain amount of "overage" may be selected by the operator. It is during the contact mode of operation that the overage or underage is established and maintained.

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The above as well as additional objectives, features, and advantages will become apparent in the following description.

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BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a view of a blown film extrusion line equipped with the improved control system of the present invention;

Figure 2 is a view of the die, sizing cage, control subassembly and rotating frame of the blown film tower of Figure 1;

Figure 3 is a view of the acoustic transducer of the improved control system of the present invention coupled to the sizing cage of the blown film extrusion line tower adjacent the extruded film tube of Figures 1 and 2;

Figure 4 is a view of the acoustic transducer of Figure 3 coupled to the sizing cage of the blown film tower, in two positions, one position being shown in phantom;

Figure 5 is a schematic and block diagram view of the preferred control system of the present invention;

Figure 6 is a schematic and block diagram view of the preferred control system of Figure 5, with special emphasis on the supervisory control unit;

Figure 7A is a schematic and block diagram view of the signals generated by the ultrasonic sensor which pertain to the position of the blown film layer;

1
2 Figure 7B is a view of the ultrasonic sensor of Figure 3 coupled to the sizing
3 cage of the blown film tower, with permissible extruded film tube operating
4 ranges indicated thereon;

5
6 Figure 8A is a flow chart of the preferred filtering process applied to the current
7 position signal generated by the acoustic transducer;

8
9 Figure 8B is a graphic depiction of the operation of the filtering system;

0
1 Figure 9 is a schematic representation of the automatic sizing and recovery
2 logic (ASRL) of Figure 6;

3
4 Figure 10 is a schematic representation of the health/state logic (HSL) of Figure
5 6;

6
7 Figure 11 is a schematic representation of the loop mode control logic (LMCL)
8 of Figure 6;

9
0 Figure 12 is a schematic representation of the volume setpoint control logic
1 (VSCL) of Figure 6;

2
3 Figure 13 is a flow chart representation of the output clamp of Figure 6.

4
5 Figure 14 is a schematic and block diagram, and flowchart views of the
6 preferred alternative emergency condition control system of the present
7 invention, which provides enhanced control capabilities for detected overblown
8 and underblown conditions, as well as when the control system determines
9 that the extruded film tube has passed out of range of the sensing transducer;

1 Figure 15 is a schematic and block diagram view of the signals generated by
2 the ultrasonic sensor which pertain to the position of the blown film layer;

3
4 Figure 16 is a view of the ultrasonic sensor of Figure 3 coupled to the sizing
5 cage of the blown film tower, with permissible extruded film tube operating
6 ranges indicated thereon;

7
8 Figure 17 is a schematic representation of the automatic sizing and recovery
9 logic (ASRL) of Figure 14;

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1 Figure 18 is a schematic representation of the health/state logic (HSL) of Figure
2 14;

3
4 Figure 19 is a schematic representation of the loop mode control logic (LMCL)
5 of Figure 14;

6
7 Figure 20 is a schematic representation of the volume setpoint control logic
8 (VSCL) of Figure 14;

9
0 Figure 21 is a flow chart representation of the output clamp of Figure 14;

1
2 Figure 22 is a schematic and block diagram view of emergency condition
3 control logic block of Figure 14;

4
5 Figures 23A through 23G depict the preferred software routines utilized in the
6 present invention, including a first filter routine which is utilized during relatively
7 unstable intervals of operation, and a second dynamic filtering routine which is
8 utilized during relatively stable intervals of operation;

9
0 Figure 24 is a graphic depiction of the normal operation of the filtering system;

1
2 Figure 25A is a graph which depicts the emergency condition control mode of
3 operation response to the detection of an underblown condition, with the
4 X-axis representing time and the Y-axis representing position of the extruded
5 film tube;
6

7 Figure 25B is a graph of the binary condition of selected operating blocks of the
8 block diagram depiction of Figure 22, and can be read in combination with
9 Figure 25A, wherein the X-axis represents time, and the Y-axis represents the
0 binary condition of selected operational blocks;
1

2 Figure 26A is a graph which depicts the emergency condition control mode of
3 operation response to the detection of an underblown condition, with the
4 X-axis representing time and the Y-axis representing position of the extruded
5 film tube;
6

7 Figure 26B is a graph of the binary condition of selected operating blocks of the
8 block diagram depiction of Figure 22, and can be read in combination with
9 Figure 26A, wherein the X-axis represents time, and the Y-axis represents the
0 binary condition of selected operational blocks;
1

2 Figure 27A is a graph which depicts the emergency condition control mode of
3 operation response to the detection of an underblown condition, with the
4 X-axis representing time and the Y-axis representing position of the extruded
5 film tube;
6

7 Figure 27B is a graph of the binary condition of selected operating blocks of the
8 block diagram depiction of Figure 22, and can be read in combination with
9 Figure 27A, wherein the X-axis represents time, and the Y-axis represents the
0 binary condition of selected operational blocks;

1
2 Figure 28 is a schematic and block diagram depiction of one embodiment of the
3 improved air flow control system of the present invention;
4

5 Figure 29 is a simplified and partial fragmentary and longitudinal section view of
6 the preferred air flow control device used with the air flow control system of
7 the present invention;
8

9 Figure 30 is a schematic depiction of a IBC blown film extrusion line equipped
0 with mass air flow sensors in communication with both a supply of cooling air
1 and an exhaust of cooling air, which may be utilized to obtain uniformity in the
2 mass air flow of the cooling air stream supply to the interior of the blown film
3 tube;
4

5 Figure 31 is a schematic depiction of an IBC blown film line equipped with
6 mass air flow sensors for controlling the supply and exhaust of air to the
7 interior of the blown film tube, and additionally equipped with a mass air flow
8 sensor for monitoring and controlling the supply of external cooling air;
9

0 Figures 32, 33, 34, and 35 are schematic depictions of an external cooling air
1 system for a blown film extrusion line, with a mass air flow sensor provided to
2 allow control over an adjustable air flow attribute modifier;
3

4 Figure 36 is a flowchart representation of computer program implemented
5 operations for achieving a feedback control loop for a blown film system;
6

7 Figure 37A is a schematic representation of the prior art control of supply and
8 exhaust blowers;
9

1 Figure 37B and Figure 37C are graphical representations of the performance
2 curves for supply and exhaust blowers;

3
4 Figure 37D is a block diagram and schematic representation of the startup
5 control apparatus of the present invention;

6
7 Figure 37E is a flowchart representation of the control routine of the startup
8 control apparatus of the present invention;

9
0 Figure 37F(1)-37F(2) is a flowchart representation of the startup mode of
1 operation of Figure 37E;

2
3 Figures 37G through 37J are flowchart representations of the run mode of
4 Figure 37E;

5
6 Figure 37K is a flowchart representation of the balance mode of Figure 37E;

7
8 Figure 37L is a pictorial representation of an array of recorded prior control
9 settings for the supply and exhaust blowers;

0
1 Figure 37M is a flowchart representation of a bubble break detection routine;

2
3 Figures 38 and 39 depict a lay flat control system.

4
5 Figures 40 through 44T depict a cage control system.

6
7 Figures 45 through 52 are a description of the cage controller.
8

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

In this detailed description of the invention, Figures 1 through 29, and accompanying text, provide a very detailed overview of an internal-bubble-cooling blown film extrusion system which is equipped with a preferred sizing control system. Figures 30 through 36, and accompanying text, provide a description of the preferred method and apparatus for cooling extruded film tubes of the present invention used either in combination with the preferred sizing control apparatus, or alone. Figures 27A through 37M depict a blower balance system. Figures 28 and 39 depict a lay flat control system. Figures 40 – end depict a cage control system and an integration of all control systems.

FIG. 1 is a view of blown film extrusion line 11, which includes a number of subassemblies which cooperate to produce plastic bags and the like from plastic resin. The main components include blown film tower 13, which provides a rigid structure for mounting and aligning the various subassemblies, extruder subassembly 15, die subassembly 17, blower subassembly 19, stack 21, sizing cage 23, collapsible frame 25, nips 27, control subassembly 28 and rollers 29.

Plastic granules are fed into hopper 31 of extruder subassembly 15. The plastic granules are melted and fed by extruder 33 and pushed into die subassembly 17, and specifically to annular die 37. The molten plastic granules emerge from annular die 37 as a molten plastic tube 39, which expands from the die diameter to a desired final diameter, which may vary typically between two to three times the die diameter.

Blower subassembly 19 includes a variety of components which cooperate together to provide a flow of cooling air to the interior of molten plastic tube 39, and also along the outer periphery of molten plastic tube 39. Blower subassembly includes blower 41 which pulls air into the system at intake 43, and exhausts air from the system at exhaust 45. The flow of air into molten plastic tube 39 is controlled at valve 47. Air is also directed along the exterior of molten plastic tube from external air ring 49, which is concentric to annular die 37. Air is supplied to the interior of molten plastic tube 39 through internal air diffuser 51. Air is pulled from the interior of molten plastic tube 39 by exhaust stack 53.

1 The streams of external and internal cooling airs serve to harden molten plastic tube
2 39 a short distance from annular die 37. The line of demarcation between the molten
3 plastic tube 39 and the hardened plastic tube 55 is identified in the trade as the
4 "frost line." Normally, the frost line is substantially at or about the location at which
5 the molten plastic tube 39 is expanded to the desired final diameter.
6

7 Adjustable sizing cage 23 is provided directly above annular die 38 and serves to
8 protect and guide the plastic tube 55 as it is drawn upward through collapsible frame
9 25 by nips 27. Afterwards, plastic tube 55 is directed through a series of rollers 57,
0 59, 61, and 63 which serve to guide the tube to packaging or other processing
1 equipment.
2

3 In some systems, rotating frame 65 is provided for rotating relative to blown film
4 tower 13. It is particularly useful in rotating mechanical feeler arms of the prior art
5 systems around plastic tube 55 to distribute the deformations. Umbilical cord 67 is
6 provided to allow electrical conductors to be routed to rotating frame 65. Rotating
7 frame 65 rotates at bearings 71, 73 relative to stationary frame 69.
8

9 Control subassembly 28 is provided to monitor and control the extrusion process,
0 and in particular the circumference of plastic tube 55. Control subassembly 28
1 includes supervisory control unit, and operator control panel 77.
2

3 FIG. 2 is a more detailed view of annular die 37, sizing cage 23, control subassembly
4 28, and rotating frame 65. As shown in FIG. 2, supervisory control unit 75 is
5 electrically coupled to operator control panel 77, valve 47, and acoustic transducer
6 79. These components cooperate to control the volume of air contained within
7 extruded film tube 81, and hence the thickness and diameter of the extruded film
8 tube 81. Valve 47 controls the amount of air directed by blower 41 into extruded film
9 tube 81 through internal air diffuser 51.
0

1 If more air is directed into extruded film tube 81 by internal air diffuser 51 than is
2 exhausted from extruded film tube 81 by exhaust stack 43, the circumference of
3 extruded film tube 81 will be increased. Conversely, if more air is exhausted from
4 the interior of extruded film tube 81 by exhaust stack 53 than is inputted into
5 extruded film tube 81 by internal air diffuser 51, the circumference of extruded film
6 tube 81 will decrease.

7
8 In the preferred embodiment, valve 41 is responsive to supervisory control unit 75
9 for increasing or decreasing the flow of air into extruded film tube 81. Operator
0 control panel 77 serves to allow the operator to select the diameter of extruded film
1 tube 81. Acoustic transducer 79 serves to generate a signal corresponding to the
2 circumference of extruded film tube 81, and direct this signal to supervisory control
3 unit 75 for comparison to the circumference setting selected by the operator at
4 operator control panel 77.

1 If the actual circumference of extruded film tube 81 exceeds the selected
2 circumference, supervisory control unit 75 operates valve 47 to restrict the passage
3 of air from blower 41 into extruded film tube 81. This results in a decrease in
4 circumference of extruded film tube 81. Conversely, if the circumference of extruded
5 film tube 81 is less than the selected circumference, supervisory control unit 75
6 operates on valve 47 to increase the flow of air into extruded film tube 81 and
7 increase its circumference. Of course, extruded film tube 81 will fluctuate in
8 circumference, requiring constant adjustment and readjustment of the inflow of air
9 by operation of supervisory control unit 75 and valve 47.

1 FIG. 3 is a view of ultrasonic sensor 89 of the improve control system of the present
2 invention coupled to sizing cage 23 adjacent extruded film tube 81. In the preferred
3 embodiment, acoustic transducer 79 comprises an ultrasonic measuring and control
4 system manufactured by Massa Products Corporation of Hingham, Mass., Model Nos.
5 M-4000, M410/215, and M450, including a Massa Products ultrasonic sensor 89. It is
6 an ultrasonic ranging and detection device which utilizes high frequency sound waves
7 which are deflected off objects and detected. In the preferred embodiment, a pair of
8 ultrasonic sensors 89 are used, one to transmit sonic pulses, and another to receive
9 sonic pulses. For purposes of simplifying the description only one ultrasonic sensor
0 89 is shown, and in fact a single ultrasonic sensor can be used, first to transmit a
1 sonic pulse and then to receive the return in an alternating fashion. The elapsed time
2 between an ultrasonic pulse being transmitted and a significant echo being received
3 corresponds to the distance between ultrasonic sensor 89 and the object being
4 sensed. Of course, the distance between the ultrasonic sensor 89 and extruded film
5 tube 81 corresponds to the circumference of extruded film tube 81. In the present
6 situation, ultrasonic sensor 89 emits an interrogating ultrasonic beam 87
7 substantially normal to extruded film tube 81 and which is deflected from the outer
8 surface of extruded film tube 81 and sensed by ultrasonic sensor 89.

9
0 The Massa Products Corporation ultrasonic measurement and control system includes
1 system electronics which utilize the duration of time between transmission and
2 reception to produce a useable electrical output such as a voltage or current. In the
3 preferred embodiment, ultrasonic sensor 89 is coupled to sizing cage 23 at
4 adjustable coupling 83. In the preferred embodiment, ultrasonic sensor 89 is
5 positioned within seven inches of extruded film tube 81 to minimize the impact of

1 ambient noise on a control system. Ultrasonic sensor 89 is positioned so that
2 interrogating ultrasonic beam 87 travels through a path which is substantially normal
3 to the outer surface of extruded film tube 81, to maximize the return signal to
4 ultrasonic sensor 89.
5

FIG. 4 is a view of ultrasonic sensor 89 of FIG. 3 coupled to sizing cage 23 of the blown film tower 13, in two positions, one position being shown in phantom. In the first position, ultrasonic sensor 89 is shown adjacent extruded film tube 81 of a selected circumference. When extruded film tube 81 is downsized to a tube having a smaller circumference, ultrasonic sensor 89 will move inward and outward relative to the central axis of the adjustable sizing cage, along with the adjustable sizing cage 23. The second position is shown in phantom with ultrasonic sensor 89' shown adjacent extruded film tube 81' of a smaller circumference. For purposes of reference, internal air diffuser 51 and exhaust stack 53 are shown in FIG. 4. The sizing cage is also movable upward and downward, so ultrasonic sensor 89 is also movable upward and downward relative to the frostline of the extruded film tube 81.

FIG. 5 is a schematic and block diagram view of the preferred control system of the present invention. The preferred acoustic transducer 79 of the present invention includes ultrasonic sensor 89 and temperature sensor 91 which cooperate to produce a current position signal which is independent of the ambient temperature. Ultrasonic sensor 89 is electrically coupled to ultrasonic electronics module 95, and temperature sensor 91 is electrically coupled to temperature electronics module 97. Together, ultrasonic electronics module 95 and temperature electronics module 97 comprise transducer electronics 93. Four signals are produced by acoustic transducer 79, including one analog signal, and three digital signals.

As shown in FIG. 5, four conductors couple transducer electronics to supervisory control unit 75. Specifically, conductor 99 routes a 0 to 10 volts DC analog input to supervisory control unit 75. Conductors 101, 103, and 105 provide digital signals to supervisory control unit 75 which correspond to a target present signal, maximum override, and minimum override. These signals will be described below in greater detail.

Supervisory control unit 75 is electrically coupled to setpoint display 109 through analog display output 107. An analog signal between 0 and 10 volts DC is provided to setpoint display 109 which displays the selected distance between ultrasonic sensor 89 and extruded film tube 81. A distance is selected by the operator through distance selector 111. Target indicator 113, preferably a light, is provided to indicate that the target (extruded film tube 81) is in range. Distance selector 111 is

1 electrically coupled to supervisory control unit 75 by distance setting conductor 119.
2 Target indicator 113 is electrically coupled to supervisory control unit 75 through
3 target present conductor 121.

4
5 Supervisory control unit 75 is also coupled via valve control conductor 123 to
6 proportional valve 125. In the preferred embodiment, proportional valve 125
7 corresponds to valve 47 of FIG. 1, and is a pressure control component
8 manufactured by Proportion air of McCordsville, Ind., Model No. BB1. Proportional
9 valve 125 translates an analog DC voltage provided by supervisory control unit 75
0 into a corresponding pressure between 0.5 and 1.2 bar. Proportional valve 125 acts
1 on flow control valve 129 through cylinder 127. Pressurized air is provided to
2 proportional valve 125 from pressurized air supply 131 through 20 micron filter 133.
3

4 FIG. 6 is a schematic and block diagram view of the preferred control system of FIG.
5 5, with special emphasis on the supervisory control unit 75. Extruded film tube 81 is
6 shown in cross-section with ultrasonic sensor 89 adjacent its outer wall. Ultrasonic
7 sensor 89 emits interrogating pulses which are bounced off of extruded film tube and
8 sensed by ultrasonic sensor 89. The time delay between transmission and reception
9 of the interrogating pulse is processed by transducer electronics 93 to produce four
0 outputs: CURRENT POSITION signal which is provided to supervisory control unit 75
1 via analog output conductor 99, digital TARGET PRESENT signal which is provided
2 over digital output 105, a minimum override signal (MIO signal) indicative of a
3 collapsing or undersized bubble which is provided over digital output conductor 103,
4 and maximum override signal (MAO signal) indicative of an overblown extruded film
5 tube 81 which is provided over a digital output conductor 101.
6

7 As shown in FIG. 6, the position of extruded film tube 81 relative to ultrasonic sensor
8 89 is analyzed and controlled with reference to a number of distance thresholds and
9 setpoints, which are shown in greater detail in FIG. 7A. All set points and thresholds
0 represent distances from reference R. The control system of the present invention
1 attempts to maintain extruded film tube 81 at a circumference which places the wall
2 of extruded film tube 81 at a tangent to the line established by reference A. The
3 distance between reference R and set point A may be selected by the user through
4 distance selector 111. This allows the user to control the distance between ultrasonic
5 sensor 89 and extruded film tube 81.

1
2 The operating range of acoustic transducer 79 is configurable by the user with
3 settings made in transducer electronics 93. In the preferred embodiment, using the
4 Massa Products transducer, the range of operation of acoustic transducer 79 is
5 between 3 to 24 inches. Therefore, the user may select a minimum circumference
6 threshold C and a maximum circumference threshold B, below and above which an
7 error signal is generated. Minimum circumference threshold C may be set by the
8 user at a distance d3 from reference R. Maximum circumference threshold B may be
9 selected by the user to be a distance d2 from reference R. In the preferred
0 embodiment, setpoint A is set a distance of 7 inches from reference R. Minimum
1 circumference threshold C is set a distance of 10.8125 inches from reference R.
2 Maximum circumference threshold B is set a distance of 4.1 inches from reference R.
3 Transducer electronics 93 allows the user to set or adjust these distances at will
4 provided they are established within the range of operation of acoustic transducer
5 79, which is between 3 and 24 inches.

6
7 Besides providing an analog indication of the distance between ultrasonic sensors 89
8 and extruded film tube 81, transducer electronics 93 also produces three digital
9 signals which provide information pertaining to the position of extruded film tube 81.
0 If extruded film tube 81 is substantially normal and within the operating range of
1 ultrasonic sensor 89, a digital "1" is provided at digital output 105. The signal is
2 representative of a TARGET PRESENT signal. If extruded film tube 81 is not within
3 the operating range of ultrasonic sensor 89 or if a return pulse is not received due to
4 curvature of extruded film tube 81, TARGET PRESENT signal of digital output 105 is
5 low. As discussed above, digital output 103 is a minimum override signal MIO. If
6 extruded film tube 81 is smaller in circumference than the reference established by
7 threshold C, minimum override signal MIO of digital output 103 is high. Conversely,
8 if circumference of extruded film tube 81 is greater than the reference established by
9 threshold C, the minimum override signal MIO is low.

0
1 Digital output 101 is for a maximum override signal MAO. If extruded film tube 81 is
2 greater than the reference established by threshold B, the maximum override signal
3 MAO is high. Conversely, if the circumference of extruded film tube 81 is less than
4 the reference established by threshold B, the output of maximum override signal
5 MAO is low.

1
2 The minimum override signal MIO will stay high as long as extruded film tube 81 has
3 a circumference less than that established by threshold C. Likewise, the maximum
4 override signal MAO will remain high for as long as the circumference of extruded
5 film tube 81 remains larger than the reference established by threshold B.
6

7 Threshold D and threshold E are also depicted in FIG. 7A. Threshold D is established
8 at a distance d4 from reference R. Threshold E is established at a distance d5 from
9 reference R. Thresholds D and E are established by supervisory control unit 75, not
0 by acoustic transducer 79. Threshold D represents a minimum circumference
1 threshold for extruded film tube 81 which differs from that established by transducer
2 electronics 93. Likewise, threshold E corresponds to a maximum circumference
3 threshold which differs from that established by acoustic transducer 79. Thresholds
4 D and E are established in the software of supervisory control unit 75, and provide a
5 redundancy of control, and also minimize the possibility of user error, since these
6 threshold are established in software, and cannot be easily changed or accidentally
7 changed. The coordination of all of these thresholds will be discussed in greater
8 detail below. In the preferred embodiment, threshold C is established at 10.8125
9 inches from reference R. Threshold E is established at 3.6 inches from reference R.
0

1 FIG. 7B is a side view of the ultrasonic sensor 89 coupled to sizing cage 23 of the
2 blown film tower 13, with permissible extruded film tube 81 operating ranges
3 indicated thereon. Setpoint A is the desired distance between ultrasonic sensor 89
4 and extruded film tube 81. Thresholds D and C are established at selected distances
5 inward from ultrasonic sensor 89, and represent minimum circumference thresholds
6 for extruded film tube 81. Thresholds B and E are established at selected distances
7 from setpoint A, and establish separate maximum circumference thresholds for
8 extruded film tube 81. As shown in FIG. 7B, extruded film tube 81 is not at setpoint
9 A. Therefore, additional air must be supplied to the interior of extruded film tube 81
0 to expand the extruded film tube 81 to the desired circumference established by
1 setpoint A.
2

1 If extruded film tube 81 were to collapse, two separate alarm conditions would be
2 registered. One alarm condition will be established when extruded film tube 81 falls
3 below threshold C. A second and separate alarm condition will be established when
4 extruded film tube 81 falls below threshold D. Extruded film tube 81 may also
5 become overblown. In an overblown condition, two separate alarm conditions are
6 possible. When extruded film tube 81 expands beyond threshold B, an alarm
7 condition is registered. When extruded film tube 81 expands further to extend
8 beyond threshold E, a separate alarm condition is registered.

9
0 As discussed above, thresholds C and B are subject to user adjustment through
1 settings in transducer electronics 93. In contrast, thresholds D and E are set in
2 computer code of supervisory control unit 75, and are not easily adjusted. This
3 redundancy in control guards against accidental or intentional missetting of the
4 threshold conditions at transducer electronics 93. The system also guards against
5 the possibility of equipment failure in transducer 79, or gradual drift in the threshold
6 settings due to deterioration, or overheating of the electronic components contained
7 in transducer electronics 93.

8
9 Returning now to FIG. 6, operator control panel 137 and supervisory control unit 75
0 will be described in greater detail. Operator control panel 137 includes setpoint
1 display 109, which serves to display the distance d1 between reference R and
2 setpoint A. Setpoint display 109 includes a 7 segment display. Distance selector 111
3 is used to adjust setpoint A. Holding the switch to the " + " position increases the
4 circumference of extruded film tube 81 by decreasing distance d1 between setpoint A
5 and reference R. Holding the switch to the " - " position decreases the diameter of
6 extruded film tube 81 by increasing the distance between reference R and setpoint
7 A.

8
9 Target indicator 113 is a target light which displays information pertaining to
0 whether extruded film tube 81 is within range of ultrasonic transducer 89, whether
1 an echo is received at ultrasonic transducer 89, and whether any alarm condition has
2 occurred. Blower switch 139 is also provided in operator control panel 137 to allow
3 the operator to selectively disconnect the blower from the control unit. As shown in
4 FIG. 6, all these components of operator control panel 137 are electrically coupled to
5 supervisory control unit 75.

1
2 Supervisory control unit 75 responds to the information provided by acoustic
3 transducer 79, and operator control panel 137 to actuate proportional valve 125.
4 Proportional valve 125 in turn acts upon pneumatic cylinder 127 to rotate flow
5 control valve 129 to control the air flow to the interior of extruded film tube 81.
6

7 With the exception of analog to digital converter 141, digital to analog converter
8 143, and digital to analog converter 145 (which are hardware items), supervisory
9 control unit 75 is a graphic representation of computer software resident in memory
0 of supervisory control unit 75. In the preferred embodiment, supervisory control unit
1 75 comprises an industrial controller, preferably a Texas Instrument brand industrial
2 controller Model No. PM550. Therefore, supervisory control unit 75 is essentially a
3 relatively low-powered computer which is dedicated to a particular piece of
4 machinery for monitoring and controlling. In the preferred embodiment, supervisory
5 control unit 75 serves to monitor many other operations of blown film extrusion line
6 11. The gauging and control of the circumference of extruded film tube 81 through
7 computer software is one additional function which is "piggybacked" onto the
8 industrial controller. Alternately, it is possible to provide an industrial controller or
9 microcomputer which is dedicated to the monitoring and control of the extruded film
0 tube 81. Of course, dedicating a microprocessor to this task is a rather expensive
1 alternative.
2

3 For purposes of clarity and simplification of description, the operation of the
4 computer program in supervisory control unit 75 have been segregated into
5 operational blocks, and presented as an amalgamation of digital hardware blocks. In
6 the preferred embodiment, these software subcomponents include: software filter
7 149, health state logic 151, automatic sizing and recovery logic 153, loop mode
8 control logic 155, volume setpoint control logic 157, and output clamp 159. These
9 software modules interface with one another, and to PI loop program 147 of
0 supervisory control unit 75. PI loop program is a software routine provided in the
1 Texas Instruments' PM550 system. The proportional controller regulates a process
2 by manipulating a control element through the feedback of a controlled output. The
3 equation for the output of a PI controller is:
4

5
$$m = K * e + K / T \text{ integral } e \text{ dt} + m_s$$

1
2 In this equation:
3

4 m = controller output

5 K = controller gain

6 e = error

7 T = reset time

8 dt = differential time

9 ms = constant

0 integral e dt = integration of all previous errors
1

2 When an error exists, it is summed (integrated) with all the previous errors, thereby
3 increasing or decreasing the output of the PI controller (depending upon whether the
4 error is positive or negative). Thus as the error term accumulates in the integral
5 term, the output changes so as to eliminate the error.
6

7 CURRENT POSITION signal is provided by acoustic transducer 79 via analog
8 output 99 to analog to digital converter 141, where the analog CURRENT
9 POSITION signal is digitized. The digitized CURRENT POSITION signal is routed
0 through software filter 149, and then to PI loop program 147. If the
1 circumference of extruded film tube 81 needs to be adjusted, PI loop program
2 147 acts through output clamp 159 upon proportional valve 125 to adjust the
3 quantity of air provided to the interior of extruded film tube 81.
4

5 Figure 8A is a flowchart of the preferred filtering process applied to CURRENT
6 POSITION signal generated by the acoustic transducer. The digitized CURRENT
7 POSITION signal is provided from analog to digital converter 141 to software
8 filter 149. The program reads the CURRENT POSITION signal in step 161.
9 Then, the software filter 149 sets SAMPLE (N) to the position signal.
0

1 In step 165, the absolute value of the difference between CURRENT POSITION
2 (SAMPLE (N)) and the previous sample (SAMPLE (N - 1)) is compared to a first
3 threshold. If the absolute value of the difference between the current sample
4 and the previous sample is less than first threshold T1, the value of SAMPLE
5 (N) is set to CFS, the current filtered sample, in step 167. If the absolute value
6 of the difference between the current sample and the previous sample exceeds
7 first threshold T1, in step 169, the CURRENT POSITION signal is disregarded,
8 and the previous position signal SAMPLE (N - 1) is substituted in its place.

9
0 Then, in step 171, the suggested change SC is calculated, by determining the
1 difference between the current filtered sample CFS and the best position
2 estimate BPE. In step 173, the suggested change SC which was calculated in
3 step 171 is compared to positive T2, which is the maximum limit on the rate of
4 change. If the suggested change is within the maximum limit allowed, in step
5 177, allowed change AC is set to the suggested change SC value. If, however,
6 in step 173, the suggested change exceeds the maximum limit allowed on the
7 rate of change, in step 175, the allowed change is set to +LT2, a default value
8 for allowed change.

9
0 In step 179, the suggested change SC is compared to the negative limit for
1 allowable rates of change, negative T2. If the suggested change SC is greater
2 than the maximum limit on negative change, in step 181, allowed change AC is
3 set to negative -LT2, a default value for negative change. However, if in step
4 179 it is determined that suggested change SC is within the maximum limit
5 allowed on negative change, in step 183, the allowed change AC is added to
6 the current best position estimate BPE, in step 183. Finally, in step 185, the
7 newly calculated best position estimate BPE is written to the PI loop program.

8
9 Software filter 149 is a two stage filter which first screens the CURRENT
0 POSITION signal by comparing the amount of change, either positive or

1 negative, to threshold T1. If the CURRENT POSITION signal, as compared to
2 the preceding position signal exceeds the threshold of T1, the current position
3 signal is discarded, and the previous position signal (SAMPLE (N - 1)) is used
4 instead. At the end of the first stage, in step 171, a suggested change SC
5 value is derived by subtracting the best position estimate BPE from the current
6 filtered sample CFS.

7
8 In the second stage of filtering, the suggested change SC value is compared to
9 positive and negative change thresholds (in steps 173 and 179). If the positive
0 or negative change thresholds are violated, the allowable change is set to a
1 preselected value, either +LT2, or -LT2. Of course, if the suggested change
2 SC is within the limits set by positive T2 and negative T2, then the allowable
3 change AC is set to the suggested change SC.

4
5 The operation of software filter 149 may also be understood with reference to
6 Figure 8B. In the graph of Figure 8B, the y-axis represents the signal level, and
7 the x-axis represents time. The signal as sensed by acoustic transducer 79 is
8 designated as input, and shown in the solid line. The operation of the first
9 stage of the software filter 149 is depicted by the current filtered sample CFS,
0 which is shown in the graph by cross-marks. As shown, the current filtered
1 sample CFS operates to ignore large positive or negative changes in the
2 position signal, and will only change when the position signal seems to have
3 stabilized for a short interval. Therefore, when changes occur in the current
4 filtered sample CFS, they occur in a plateau-like manner.

5
6 In stage two of the software filter 149, the current filtered sample CFS is
7 compared to the best position estimate BPE, to derive a suggested change SC
8 value. The suggested SC is then compared to positive and negative thresholds
9 to calculate an allowable change AC which is then added to the best position
0 estimate BPE. Figure 8B shows that the best position estimate BPE signal only

1 gradually changes in response to an upward drift in the POSITION SIGNAL.
2 The software filtering system 149 of the present invention renders the control
3 apparatus relatively unaffected by random noise, but capable of tracking the
4 more "gradual" changes in bubble position.
5

6 Experimentation has revealed that the software filtering system of the present
7 invention operates best when the position of extruded film tube 81 is sampled
8 between 20 to 30 times per second. At this sampling rate, one is less likely to
9 incorrectly identify noise as a change in circumference of extruded film tube
0 81. The preferred sampling rate accounts for the common noise signals
1 encountered in blown film extrusion liner.
2

3 Optional thresholds have also been derived through experimentation. In the
4 first stage of filtering, threshold T1 is established as roughly one percent of the
5 operating range of acoustic transducer 79, which in the preferred embodiment
6 is twenty-one meters (24 inches less 3 inches). In the second stage of filter,
7 thresholds +LT2 and -LT2 are established as roughly 0.30% of the operating
8 range of acoustic transducer 79.
9

0 Figure 9 is a schematic representation of the automatic sizing and recovery
1 logic ASRL of supervisory control unit 75. As stated above, this figure is a
2 hardware representation of a software routine. ASRL 153 is provided to
3 accommodate the many momentary false indications of maximum and
4 minimum circumference violations which may be registered due to noise, such
5 as the noise created due to air flow between acoustic transducer 79 and
6 extruded film tube 81. The input from maximum alarm override MAO is "ored"
7 with high alarm D, from the PI loop program, at "or" operator 191. High alarm
8 D is the signal generated by the program in supervisory control unit 75 when
9 the circumference of extruded film tube 81 exceeds threshold D of Figure 7A.
0 If a maximum override MAO signal exists, or if a high alarm condition D exists,

1 the output of "or" operator 191 goes high, and actuates delay timer 193.

2
3 Likewise, minimum override MIO signal is "ored" at "or" operator 195 with low
4 alarm E. If a minimum override signal is present, or if a low alarm condition E
5 exists, the output of "or" operator 195 goes high, and is directed to delay timer
6 197. Delay timers 193, 197 are provided to prevent an alarm condition unless
7 the condition is held for 800 milliseconds continuously. Every time the input of
8 delay timers 193, 197 goes low, the timer resets and starts from 0. This
9 mechanism eliminates many false alarms.

0
1 If an alarm condition is held for 800 milliseconds continuously, an
2 OVERBLOWN or UNDERBLOWN signal is generated, and directed to the health
3 state logic 151. Detected overblown or underblown conditions are "ored" at
4 "or" operator 199 to provide a REQUEST MANUAL MODE signal which is
5 directed to loop mode control logic 155.

6
7 Figure 10 is a schematic representation of the health-state logic 151 of Figure
8 6. The purpose of this logic is to control the target indicator 113 of operator
9 control panel 137. When in non-error operation, the target indicator 113 is on
0 if the blower is on, and the TARGET PRESENT signal from digital output 105 is
1 high. When an error is sensed in the maximum override MAO or minimum
2 override MIO lines, the target indicator 113 will flash on and off in one half
3 second intervals.

4
5 In health-state logic HSL 151, the maximum override signal MAO is inverted at
6 inverter 205. Likewise, the minimum override signal is inverted at inverter 207.

7
8 "And" operator 209 serves to "and" the inverted maximum override signal
9 MAO, with the OVERBLOWN signal, and high alarm signal D. A high output
0 from "and" operator 209 indicates that something is wrong with the calibration

1 of acoustic transducer 79.

2
3 Likewise, "and" operator 213 serves to "and" the inverted minimum override
4 signal MIO, with the OVERBLOWN signal, and low alarm signal E. If the output
5 of "and" operator 213 is high, something is wrong with the calibration of
6 acoustic transducer 79. The outputs from "and" operators 209, 213 are
7 combined in "or" operator 215 to indicate an error with either the maximum or
8 minimum override detection systems. The output of "or" operator 215 is
9 channeled through oscillator 219, and inverted at inverter 217. "And" operator
0 211 serves to "and" the TARGET PRESENT signal, blower signal, and inverted
1 error signal from "or" operator 215. The output of "and" operator of 211 is
2 connected to target indicator 113.

3
4 If acoustic transducer 79 is properly calibrated, the target is within range and
5 normal to the sonic pulses, and the blower is on, target indicator 113 will be
6 on. If the target is within range and normal to the sonic pulses, the blower is
7 on, but acoustic transducer 79 is out of calibration, target indicator 113 will be
8 on, but will be blinking. The blinking signal indicates that acoustic transducer
9 79, and in particular transducer electronics 93, must be recalibrated.

0
1 Figure 11 is a schematic representation of loop mode control logic LMCL of
2 Figure 6. The purpose of this software module is coordinate the transition in
3 modes of operation. Specifically, this software module coordinates automatic
4 startup of the blown film extrusion process, as well as changes in mode
5 between an automated "cascade" mode and a manual mode, which is the
6 required mode of the PI controller to enable under and overblown conditions of
7 the extruded film tube 81 circumference. The plurality of input signals are
8 provided to loop mode control logic 155, including: BLOWER ON, REQUEST
9 MANUAL MODE, PI LOOP IN CASCADE MODE, UNDERBLOWN and
0 OVERBLOWN. Loop mode control logic LMCL 155 provides two output

1 signals: MANUAL MODE, and CASCADE MODE.

2
3 Figure 11 includes a plurality of digital logic blocks which are representative of
4 programming operations. "Or" operator 225 "ores" the inverted BLOWER ON
5 SIGNAL to the REQUEST MANUAL MODE SIGNAL. "And" operator 227
6 "ands" the inverted REQUEST MANUAL MODE SIGNAL with an inverted
7 MANUAL MODE SIGNAL, and the BLOWER ON SIGNAL. "And" operator 229
8 "ands" the REQUEST MANUAL MODE SIGNAL to the inverted CASCADE
9 MODE SIGNAL. This prevents MANUAL MODE and CASCADE MODE from
0 both being on at the same time. "And" operator 231 "ands" the MANUAL
1 MODE SIGNAL, the inverted UNDERBLOWN SIGNAL, and the OVERBLOWN
2 SIGNAL. "And" operator 233 "ands" the MANUAL MODE SIGNAL with the
3 UNDERBLOWN SIGNAL. This causes the overblown condition to prevail in the
4 event a malfunction causes both underblown and overblown conditions to be
5 on. Inverters 235, 237, 239, 241, and 243 are provided to invert the inputted
6 output signals of loop mode control logic 155 were needed. Software one-shot
7 245 is provided for providing a momentary response to a condition. Software
8 one-shot 245 includes "and" operator 247, off-delay 249, and inverter 251.

9
0 The software of loop mode control logic 155 operates to ensure that the
1 system is never in MANUAL MODE, and CASCADE MODE at the same time.
2 When manual mode is requested by REQUEST MANUAL MODE, loop mode
3 control logic 155 causes MANUAL MODE to go high. When manual mode is
4 not requested, loop mode control logic 155 operates to cause CASCADE MODE
5 to go high. MANUAL MODE and CASCADE MODE will never be high at the
6 same time. Loop mode control logic 155 also serves to ensure that the system
7 provides a "bumpless transfer" when mode changes occur. The term "cascade
8 mode" is understood in the automation industries as referring to an automatic
9 mode which will read an adjustable setpoint.
0

1 Loop mode control logic 155 will also allow for automatic startup of the blown
2 film extrusion process. At startup, UNDERBLOWN SIGNAL is high, PI LOOP IN
3 CASCADE MODE is low, BLOWER ON SIGNAL is high. These inputs (and
4 inverted inputs) are combined at "and" operators 231, 233. At startup, "and"
5 operator 233 actuates logic block 253 to move the maximum air flow value
6 address to the PI loop step 261. At startup, the MANUAL MODE SIGNAL is
7 high. For the PI loop controller of the preferred embodiment, when MANUAL
8 MODE is high, the value contained in PI loop output address is automatically
9 applied to proportional valve 125. This results in actuation of proportional
0 valve 125 to allow maximum air flow to start the extruded film tube 81.

1
2 When extruded film tube 81 extends in size beyond the minimum threshold (C
3 and D of Figure 7A), the UNDERBLOWN SIGNAL goes low, and the PI LOOP IN
4 CASCADE MODE signal goes high. This causes software one-shot 245 to
5 trigger, causing logic blocks 265, 267 to push an initial bias value contained in
6 a program address onto the PI loop. Simultaneously, logic blocks 269, 271
7 operate to place the selected setpoint value A onto volume-setpoint control
8 logic VSCL 157. Thereafter, volume-setpoint control logic VSCL 157 alone
9 serves to communicate changes in setpoint value A to PI loop program 147.

1 If an overblown or underblown condition is detected for a sufficiently long
2 period of time, the controller will request a manual mode by causing REQUEST
3 MANUAL MODE SIGNAL to go high. If REQUEST MANUAL MODE goes high,
4 loop mode control logic LMCL 155 supervises the transfer through operation of
5 the logic blocks.

6
7 Loop mode control logic LMCL 155 also serves to detected overblown and
8 underblown conditions. If an overblown or underblown condition is detected by
9 the control system, REQUEST MANUAL MODE goes high, and the appropriate
0 OVERBLOWN or UNDERBLOWN signal goes high. The logic operators of loop

1 mode control logic LMCL 155 operate to override the normal operation of the
2 control system, and cause maximum or minimum air flow by putting the
3 maximum air flow address 261 or minimum air flow address 263 to the PI
4 output address. As stated above, when MANUAL MODE is high, these
5 maximum or minimum air flow address values are outputted directly to
6 proportional valve 125. Thus, when the extruded film tube 81 is overblown,
7 loop mode control logic LMCL 155 operates to immediately cause proportional
8 valve 125 to minimize air flow to extruded film tube 81. Conversely, if an
9 underblown condition is detected, loop mode control logic LMCL 155 causes
0 proportional valve 125 to immediately maximize air flow to extruded film tube
1 81.

2
3 Figure 12 depicts the operation of volume-setpoint control logic VSCL 157.

4
5 Volume setpoint control logic VSCL 157 operates to increase or decrease
6 setpoint A in response to changes made by the operator at distance selector
7 111 of operator control panel 137, when the PI loop program 147 is in cascade
8 mode, i.e. when PI LOOP IN CASCADE MODE signal is high. The INCREASE
9 SETPOINT, DECREASE SETPOINT, and PI LOOP IN CASCADE MODE signals
0 are logically combined at "and" operators 283, and 287. These "and"
1 operators act on logic blocks 285, 289 to increase or decrease the setpoint
2 contained in remote setpoint address 291. When the setpoint is either
3 increased or decreased, logic block 293 operates to add the offset to the
4 remote setpoint for display, and forwards the information to digital to analog
5 converter 143, for display at setpoint display 109 of operator control panel
6 137. The revised remote setpoint address is then read by the PI loop program
7 147.

8
9 Figure 13 is a flowchart drawing of output clamp 159. The purpose of this
0 software routine is to make sure that the PI loop program 147 does not over

1 drive the flow control valve 129 past a usable limit. Flow control valve 129
2 operates by moving a vane to selectively occlude stationary openings. If the
3 moving vane is over driven, the rotary valve will begin to open when the PI loop
4 calls for complete closure. In step 301, the output of the PI loop program 147
5 is read. In step 303, the output of PI loop is compared to a maximum output.
6 If it exceeds the maximum output, the PI output is set to a predetermined
7 maximum output in step 305. If the output of PI loop does not exceed the
8 maximum output, in step 307, the clamped PI output is written to the
9 proportional valve 125 through digital to analog converter 145.
0

1 Figures 14, through 27 will be used to describe an alternative emergency
2 condition control mode of operation which provides enhanced control
3 capabilities, especially when an overblown or underblown condition is detected
4 by the control system, or when the system indicates that the extruded film
5 tube is out of range of the position-sensing transducer. In this alternative
6 emergency condition control mode of operation, the valve of the estimated
7 position is advanced to a preselected valve and a more rapid change in the
8 estimated position signal is allowed than during previously discussed operating
9 conditions, and is particularly useful when an overblown or underblown
0 condition is detected. In the event the control system indicates that the
1 extruded film tube is out of range of the sensing transducer, the improved
2 control system supplies an estimated position which, in most situations, is a
3 realistic estimation of the position of the extruded film tube relative to the
4 sensing transducer, thus preventing false indications of the extruded film tube
5 being out of range of the sensing transducer from adversely affecting the
6 estimated position of the extruded film tube, greatly enhancing operation of the
7 control system. In the event an overblown condition is detected, the improved
8 control system supplies an estimated position which corresponds to the
9 distance boundary established for detecting an overflow condition. In the event
0 an underblown condition is detected, the improved control system supplies an

1 estimated position which corresponds to the distance boundary established for
2 detecting an underblown condition.

3
4 Figures 14, through 27 are a block diagram, schematic, and flowchart
5 representation of the preferred embodiment of a control system which is
6 equipped with the alternative emergency condition control mode of operation.
7 Figures 25, 26, and 27 provide graphic examples of the operation of this
8 alternative emergency condition control mode of operation.

9
0 Figure 14 is a schematic and block diagram view of the preferred alternative
1 control system 400 of the present invention of Figure 5, with special emphasis
2 on the supervisory control unit 75, and is identical in almost all respects to the
3 supervisory control unit 75 which is depicted in Figure 6; therefore, identical
4 referenced numerals are used to identify the various components of alternative
5 control system 400 of Figure 14 as are used in the control system depicted in
6 Figure 6.

7
8 Extruded film tube 81 is shown in cross-section with ultrasonic sensor 89
9 adjacent its outer wall. Ultrasonic sensor 89 emits interrogating pulses which
0 are bounced off of extruded film tube and sensed by ultrasonic sensor 89. The
1 time delay between transmission and reception of the interrogating pulse is
2 processed by transducer electronics 93 to produce four outputs: CURRENT
3 POSITION signal which is provided to supervisory control unit 75 via analog
4 output conductor 99, digital TARGET PRESENT signal which is provided over
5 digital output 105, a minimum override signal (MIO signal) indicative of a
6 collapsing or undersized bubble which is provided over digital output conductor
7 103, and maximum override signal (MAO signal) indicative of an overblown
8 extruded film tube 81 which is provided over a digital output conductor 101.

9
0 As shown in Figure 14, the position of extruded film tube 81 relative to

1 ultrasonic sensor 89 is analyzed and controlled with reference to a number of
2 distance thresholds and setpoints, which are shown in greater detail in Figure
3 15. All set points and thresholds represent distances from reference R. The
4 control system of the present invention attempts to maintain extruded film tube
5 81 at a circumference which places the wall of extruded film tube 81 at a
6 tangent to the line established by reference A. The distance between reference
7 R and set point A may be selected by the user through distance selector 111.
8 This allows the user to control the distance between ultrasonic sensor 89 and
9 extruded film tube 81.

1 The operating range of acoustic transducer 79 is configurable by the user with
2 settings made in transducer electronics 93. In the preferred embodiment, using
3 the Massa Products transducer, the range of operation of acoustic transducer
4 79 is between 3 to 24 inches. Therefore, the user may select a minimum
5 circumference threshold C and a maximum circumference threshold B, below
6 and above which an error signal is generated. Minimum circumference
7 threshold C may be set by the user at a distance d_3 from reference R.
8 Maximum circumference threshold B may be selected by the user to be a
9 distance d_2 from reference R. In the preferred embodiment, setpoint A is set a
0 distance of 7 inches from reference R. Minimum circumference threshold C is
1 set a distance of 10.8125 inches from reference R. Maximum circumference
2 threshold B is set a distance of 4.1 inches from reference R. Transducer
3 electronics 93 allows the user to set or adjust these distances at will provided
4 they are established within the range of operation of acoustic transducer 79,
5 which is between 3 and 24 inches.

7 Besides providing an analog indication of the distance between ultrasonic
8 sensors 89 and extruded film tube 81, transducer electronics 93 also produces
9 three digital signals which provide information pertaining to the position of
0 extruded film tube 81. If extruded film tube 81 is substantially normal and

1 within the operating range of ultrasonic sensor 89, a digital "1" is provided at
2 digital output 105. The signal is representative of a TARGET PRESENT signal.
3 If extruded film tube 81 is not within the operating range of ultrasonic sensor
4 89 or if a return pulse is not received due to curvature of extruded film tube 81,
5 TARGET PRESENT signal of digital output 105 is low. As discussed above,
6 digital output 103 is a minimum override signal MIO. If extruded film tube 81 is
7 smaller in circumference than the reference established by threshold C,
8 minimum override signal MIO of digital output 103 is high. Conversely, if
9 circumference of extruded film tube 81 is greater than the reference established
0 by threshold C, the minimum override signal MIO is low.

1
2 Digital output 101 is for a maximum override signal MAO. If extruded film tube
3 81 is greater than the reference established by threshold B, the maximum
4 override signal MAO is high. Conversely, if the circumference of extruded film
5 tube 81 is less than the reference established by threshold B, the output of
6 maximum override signal MAO is low.

7
8 The minimum override signal MIO will stay high as long as extruded film tube
9 81 has a circumference less than that established by threshold C. Likewise,
0 the maximum override signal MAO will remain high for as long as the
1 circumference of extruded film tube 81 remains larger than the reference
2 established by threshold B.

3
4 Threshold D and threshold E are also depicted in Figure 15. Threshold D is
5 established at a distance d4 from reference R. Threshold E is established at a
6 distance d5 from reference R. Thresholds D and E are established by
7 supervisory control unit 75, not by acoustic transducer 79. Threshold D
8 represents a minimum circumference threshold for extruded film tube 81 which
9 differs from that established by transducer electronics 93. Likewise, threshold
0 E corresponds to a maximum circumference threshold which differs from that

established by acoustic transducer 79. Thresholds D and E are established in the software of supervisory control unit 75, and provide a redundancy of control, and also minimize the possibility of user error, since these thresholds are established in software, and cannot be easily changed or accidentally changed. The coordination of all of these thresholds will be discussed in greater detail below. In the preferred embodiment, threshold C is established at 10.8125 inches from reference R. Threshold E is established at 4.125" inches from reference R.

Figure 16 is a side view of the ultrasonic sensor 89 coupled to sizing cage 23 of the blown film tower 13, with permissible extruded film tube 81 operating ranges indicated thereon. Setpoint A is the desired distance between ultrasonic sensor 89 and extruded film tube 81. Thresholds D and C are established at selected distances inward from ultrasonic sensor 89, and represent minimum circumference thresholds for extruded film tube 81. Thresholds B and E are established at selected distances from setpoint A, and establish separate maximum circumference thresholds for extruded film tube 81. As shown in Figure 16, extruded film tube 81 is not at setpoint A. Therefore, additional air must be supplied to the interior of extruded film tube 81 to expand the extruded film tube 81 to the desired circumference established by setpoint A.

If extruded film tube 81 were to collapse, two separate alarm conditions would be registered. One alarm condition will be established when extruded film tube 81 falls below threshold C. A second and separate alarm condition will be established when extruded film tube 81 falls below threshold D. Extruded film tube 81 may also become overblown. In an overblown condition, two separate alarm conditions are possible. When extruded film tube 81 expands beyond threshold B, an alarm condition is registered. When extruded film tube 81 expands further to extend beyond threshold E, a separate alarm condition is registered.

1
2 As discussed above, thresholds C and B are subject to user adjustment through
3 settings in transducer electronics 93. In contrast, thresholds D and E are set in
4 computer code of supervisory control unit 75, and are not easily adjusted. This
5 redundancy in control guards against accidental or intentional missetting of the
6 threshold conditions at transducer electronics 93. The system also guards
7 against the possibility of equipment failure in transducer 79, or gradual drift in
8 the threshold settings due to deterioration, or overheating of the electronic
9 components contained in transducer electronics 93.
0

1 Returning now to Figure 14, operator control panel 137 and supervisory control
2 unit 75 will be described in greater detail. Operator control panel 137 includes
3 setpoint display 109, which serves to display the distance d1 between
4 reference R and setpoint A. Setpoint display 109 includes a 7 segment display.

5 Distance selector 111 is used to adjust setpoint A. Holding the switch to the
6 "+" position increases the circumference of extruded film tube 81 by
7 decreasing distance d1 between setpoint A and reference R. Holding the
8 switch to the "-" position decreases the diameter of extruded film tube 81 by
9 increasing the distance between reference R and setpoint A.
0

1 Target indicator 113 is a target light which displays information pertaining to
2 whether extruded film tube 81 is within range of ultrasonic transducer 89,
3 whether an echo is received at ultrasonic transducer 89, and whether any error
4 condition has occurred. Blower switch 139 is also provided in operator control
5 panel 137 to allow the operator to selectively disconnect the blower from the
6 control unit. As shown in Figure 14, all these components of operator control
7 panel 137 are electrically coupled to supervisory control unit 75.
8

9 Supervisory control unit 75 responds to the information provided by acoustic
0 transducer 79, and operator control panel 137 to actuate proportional valve

1 125. Proportional valve 125 in turn acts upon pneumatic cylinder 127 to rotate
2 flow control valve 129 to control the air flow to the interior of extruded film
3 tube 81.
4

5 With the exception of analog to digital converter 141, digital to analog
6 converter 143, and digital to analog converter 145 (which are hardware items),
7 supervisory control unit 75 is a graphic representation of computer software
8 resident in memory of supervisory control unit 75. In one embodiment,
9 supervisory control unit 75 comprises an industrial controller, preferably a
0 Control Microsystems brand industrial controller Model No. T6000. Therefore,
1 supervisory control unit 75 is essentially a relatively low-powered computer
2 which is dedicated to a particular piece of machinery for monitoring and
3 controlling. In the preferred embodiment, supervisory control unit 75 serves to
4 monitor many other operations of blown film extrusion line 11. The gauging
5 and control of the circumference of extruded film tube 81 through computer
6 software is one additional function which is "piggybacked" onto the industrial
7 controller. Alternately, it is possible to provide an industrial controller or
8 microcomputer which is dedicated to the monitoring and control of the
9 extruded film tube 81. Of course, dedicating a microprocessor to this task is a
0 rather expensive alternative.
1

2 For purposes of clarity and simplification of description, the operation of the
3 computer program in supervisory control unit 75 have been segregated into
4 operational blocks, and presented as an amalgamation of digital hardware
5 blocks. In the preferred embodiment, these software subcomponents include:
6 software filter 149, emergency condition control mode logic 150, health state
7 logic 151, automatic sizing and recovery logic 153, loop mode control logic
8 155, volume setpoint control logic 157, and output clamp 159. These
9 software modules interface with one another, and to PI loop program 147 of
0 supervisory control unit 75. PI loop program is a software routine provided in

1 the Control Microsystems' T6000 system. The proportional controller regulates
2 a process by manipulating a control element through the feedback of a
3 controlled output. The equation for the output of a PI controller is:

4
$$m = K * \int e + K/T \ e \ dt + ms$$

5
6 In this equation:

7 m = controller output

8 K = controller gain

9 e = error

0 T = reset time

1 dt = differential time

2 ms = constant

3 $\int e \ dt$ = integration of all previous errors

4
5
6 When an error exists, it is summed (integrated) with all the previous errors,
7 thereby increasing or decreasing the output of the PI controller (depending upon
8 whether the error is positive or negative). Thus as the error term accumulates
9 in the integral term, the output changes so as to eliminate the error.

0
1 CURRENT POSITION signal is provided by acoustic transducer 79 via analog
2 output 99 to analog to digital converter 141, where the analog CURRENT
3 POSITION signal is digitized. The digitized CURRENT POSITION signal is routed
4 through software filter 149, and then to PI loop program 147. If the
5 circumference of extruded film tube 81 needs to be adjusted, PI loop program
6 147 acts through output clamp 159 upon proportional valve 125 to adjust the
7 quantity of air provided to the interior of extruded film tube 81.

8
9 Figure 17 is a schematic representation of the automatic sizing and recovery
0 logic ASRL of supervisory control unit 75. As stated above, this figure is a

1 hardware representation of a software routine. ASRL 153 is provided to
2 accommodate the many momentary false indications of maximum and
3 minimum circumference violations which may be registered due to noise, such
4 as the noise created due to air flow between acoustic transducer 79 and
5 extruded film tube 81. The input from maximum alarm override MAO is "ored"
6 with high alarm D, from the PI loop program, at "or" operator 191. High alarm
7 D is the signal generated by the program in supervisory control unit 75 when
8 the circumference of extruded film tube 81 exceeds threshold D of Figure 15.
9 If a maximum override MAO signal exists, or if a high alarm condition D exists,
0 the output of "or" operator 191 goes high, and actuates delay timer 193.

1
2 Likewise, minimum override MIO signal is "ored" at "or" operator 195 with low
3 alarm E. If a minimum override signal is present, or if a low alarm condition E
4 exists, the output of "or" operator 195 goes high, and is directed to delay timer
5 197. Delay timers 193, 197 are provided to prevent an alarm condition unless
6 the condition is held for 800 milliseconds continuously. Every time the input of
7 delay timers 193, 197 goes low, the timer resets and starts from 0. This
8 mechanism eliminates many false alarms.

9
0 If an alarm condition is held for 800 milliseconds continuously, an
1 OVERBLOWN or UNDERBLOWN signal is generated, and directed to the health
2 state logic 151. Detected overblown or underblown conditions are "ored" at
3 "or" operator 199 to provide a REQUEST MANUAL MODE signal which is
4 directed to loop mode control logic 155.

5
6 Figure 18 is a schematic representation of the health-state logic 151 of Figure
7 14. The purpose of this logic is to control the target indicator 113 of operator
8 control panel 137. When in non-error operation, the target indicator 113 is on
9 if the blower is on, and the TARGET PRESENT signal from digital output 105 is
0 high. When an error is sensed in the maximum override MAO or minimum

1 override MIO lines, the target indicator 113 will flash on and off in one half
2 second intervals.

3
4 In health-state logic HSL 151, the maximum override signal MAO is inverted at
5 inverter 205. Likewise, the minimum override signal is inverted at inverter 207.

6
7 "And" operator 209 serves to "and" the inverted maximum override signal
8 MAO, with the OVERBLOWN signal, and high alarm signal D. A high output
9 from "and" operator 209 indicates that something is wrong with the calibration
0 of acoustic transducer 79.

1
2 Likewise, "and" operator 213 serves to "and" the inverted minimum override
3 signal MIO, with the OVERBLOWN signal, and low alarm signal E. If the output
4 of "and" operator 213 is high, something is wrong with the calibration of
5 acoustic transducer 79. The outputs from "and" operators 209, 213 are
6 combined in "or" operator 215 to indicate an error with either the maximum or
7 minimum override detection systems. The output of "or" operator 215 is
8 channeled through oscillator 219, and inverted at inverter 217. "And" operator
9 211 serves to "and" the TARGET PRESENT signal, blower signal, and inverted
0 error signal from "or" operator 215. The output of "and" operator of 211 is
1 connected to target indicator 113.

2
3 If acoustic transducer 79 is properly calibrated, the target is within range and
4 normal to the sonic pulses, and the blower is on, target indicator 113 will be
5 on. If the target is within range and normal to the sonic pulses, the blower is
6 on, but acoustic transducer 79 is out of calibration, target indicator 113 will be
7 on, but will be blinking. The blinking signal indicates that acoustic transducer
8 79, and in particular transducer electronics 93, must be recalibrated.

9
0 Figure 19 is a schematic representation of loop mode control logic LMCL of

1 Figure 14. The purpose of this software module is coordinate the transition in
2 modes of operation. Specifically, this software module coordinates automatic
3 startup of the blown film extrusion process, as well as changes in mode
4 between an automated "cascade" mode and a manual mode, which is the
5 required mode of the PI controller to enable under and overblown conditions of
6 the extruded film tube 81 circumference. The plurality of input signals are
7 provided to loop mode control logic 155, including: BLOWER ON, REQUEST
8 MANUAL MODE, PI LOOP IN CASCADE MODE, UNDERBLOWN and
9 OVERBLOWN. Loop mode control logic LMCL 155 provides two output
0 signals: MANUAL MODE, and CASCADE MODE.

1
2 Figure 19 includes a plurality of digital logic blocks which are representative of
3 programming operations. "Or" operator 225 "ores" the inverted BLOWER ON
4 SIGNAL to the REQUEST MANUAL MODE SIGNAL. "And" operator 227
5 "ands" the inverted REQUEST MANUAL MODE SIGNAL with an inverted
6 MANUAL MODE SIGNAL, and the BLOWER ON SIGNAL. "And" operator 229
7 "ands" the REQUEST MANUAL MODE SIGNAL to the inverted CASCADE
8 MODE SIGNAL. This prevents MANUAL MODE and CASCADE MODE from
9 both being on at the same time. "And" operator 231 "ands" the MANUAL
0 MODE SIGNAL, the inverted UNDERBLOWN SIGNAL, and the OVERBLOWN
1 SIGNAL. "And" operator 233 "ands" the MANUAL MODE SIGNAL with the
2 UNDERBLOWN SIGNAL. This causes the overblown condition to prevail in the
3 event a malfunction causes both underblown and overblown conditions to be
4 on. Inverters 235, 237, 239, 241, and 243 are provided to invert the inputted
5 output signals of loop mode control logic 155 were needed. Software one-shot
6 245 is provided for providing a momentary response to a condition. Software
7 one-shot 245 includes "and" operator 247, off-delay 249, and inverter 251.

8
9 The software of loop mode control logic 155 operates to ensure that the
0 system is never in MANUAL MODE, and CASCADE MODE at the same time.

1 When manual mode is requested by REQUEST MANUAL MODE, loop mode
2 control logic 155 causes MANUAL MODE to go high. When manual mode is
3 not requested, loop mode control logic 155 operates to cause CASCADE MODE
4 to go high. MANUAL MODE and CASCADE MODE will never be high at the
5 same time. Loop mode control logic 155 also serves to ensure that the system
6 provides a "bumpless transfer" when mode changes occur. The term "cascade
7 mode" is understood in the automation industries as referring to an automatic
8 mode which will read an adjustable setpoint.

9
0 Loop mode control logic 155 will also allow for automatic startup of the blown
1 film extrusion process. At startup, UNDERBLOWN SIGNAL is high, PI LOOP IN
2 CASCADE MODE is low, BLOWER ON SIGNAL is high. These inputs (and
3 inverted inputs) are combined at "and" operators 231, 233. At startup, "and"
4 operator 233 actuates logic block 253 to move the maximum air flow value
5 address to the PI loop step 261. At startup, the MANUAL MODE SIGNAL is
6 high. For the PI loop controller of the preferred embodiment, when MANUAL
7 MODE is high, the value contained in PI loop output address is automatically
8 applied to proportional valve 125. This results in actuation of proportional
9 valve 125 to allow maximum air flow to start the extruded film tube 81.

1 When extruded film tube 81 extends in size beyond the minimum threshold (C
2 and D of Figure 15), the UNDERBLOWN SIGNAL goes low, and the PI LOOP IN
3 CASCADE MODE signal goes high. This causes software one-shot 245 to
4 trigger, causing logic blocks 265, 267 to push an initial bias value contained in
5 a program address onto the PI loop. Simultaneously, logic blocks 269, 271
6 operate to place the selected setpoint value A onto volume-setpoint control
7 logic VSCL 157. Thereafter, volume-setpoint control logic VSCL 157 alone
8 serves to communicate changes in setpoint value A to PI loop program 147.

9
0 If an overblown or underblown condition is detected for a sufficiently long

1 period of time, the controller will request a manual mode by causing REQUEST
2 MANUAL MODE SIGNAL to go high. If REQUEST MANUAL MODE goes high,
3 loop mode control logic LMCL 155 supervises the transfer through operation of
4 the logic blocks.

5
6 Loop mode control logic LMCL 155 also serves to detected overblown and
7 underblown conditions. If an overblown or underblown condition is detected by
8 the control system, REQUEST MANUAL MODE goes high, and the appropriate
9 OVERBLOWN or UNDERBLOWN signal goes high. The logic operators of loop
0 mode control logic LMCL 155 operate to override the normal operation of the
1 control system, and cause maximum or minimum air flow by putting the
2 maximum air flow address 261 or minimum air flow address 263 to the PI
3 output address. As stated above, when MANUAL MODE is high, these
4 maximum or minimum air flow address values are outputted directly to
5 proportional valve 125. Thus, when the extruded film tube 81 is overblown,
6 loop mode control logic LMCL 155 operates to immediately cause proportional
7 valve 125 to minimize air flow to extruded film tube 81. Conversely, if an
8 underblown condition is detected, loop mode control logic LMCL 155 causes
9 proportional valve 125 to immediately maximize air flow to extruded film tube
0 81.

1
2 Figure 20 depicts the operation of volume-setpoint control logic VSCL 157.

3
4 Volume setpoint control logic VSCL 157 operates to increase or decrease
5 setpoint A in response to changes made by the operator at distance selector
6 111 of operator control panel 137, when the PI loop program 147 is in cascade
7 mode, i.e. when PI LOOP IN CASCADE MODE signal is high. The INCREASE
8 SETPOINT, DECREASE SETPOINT, and PI LOOP IN CASCADE MODE signals
9 are logically combined at "and" operators 283, and 287. These "and"
0 operators act on logic blocks 285, 289 to increase or decrease the setpoint

1 contained in remote setpoint address 291. When the setpoint is either
2 increased or decreased, logic block 293 operates to add the offset to the
3 remote setpoint for display, and forwards the information to digital to analog
4 converter 143, for display at setpoint display 109 of operator control panel
5 137. The revised remote setpoint address is then read by the PI loop program
6 147.

7
8 Figure 21 is a flowchart drawing of output clamp 159. The purpose of this
9 software routine is to make sure that the PI loop program 147 does not over
0 drive the flow control valve 129 past a usable limit. Flow control valve 129
1 operates by moving a vane to selectively occlude stationary openings. If the
2 moving vane is over driven, the rotary valve will begin to open when the PI loop
3 calls for complete closure. In step 301, the output of the PI loop program 147
4 is read. In step 303, the output of PI loop is compared to a maximum output.
5 If it exceeds the maximum output, the PI output is set to a predetermined
6 maximum output in step 305. If the output of PI loop does not exceed the
7 maximum output, in step 307, the clamped PI output is written to the
8 proportional valve 125 through digital to analog converter 145.

9
0 As shown in Figure 14, emergency condition control mode logic 150 is
1 provided in supervisory control unit 75, and is shown in detail in Figure 22. As
2 shown in Figure 22, emergency condition control mode logic 150 receives three
3 input signals: the OVER BLOWN signal; the UNDERBLOWN signal; and the
4 TARGET filter signal. The emergency condition control mode logic 150
5 provides as an output two variables to software filter 149, including: "SPEED
6 HOLD"; and "ALIGN HOLD". The OVERBLOWN signal is directed to
7 anticipation state "or" gate 403 and to inverter 405. The UNDERBLOWN signal
8 is directed to anticipation state "or" gate 403 and to inverter 407. The
9 TARGET signal is directed through inverter 401 to anticipation state "or" gate
0 403, and to "and" gate 409. The output of anticipation "or" gate 403 is the

"or" combination of OVERBLOWN signal, and the inverted TARGET signal. Anticipation state "or" gate 403 and "and" gate 419 cooperate to provide a locking logic loop. The output of "or" gate 403 is provided as an input to "and" gate 419. The other input to "and" gate 419 is the output of inverter 417. The output of inverter 417 can be considered as a "unlocking" signal. If the OVERBLOWN signal or UNDERBLOWN signal is high, or the inverted TARGET signal is high, the output of anticipation state "or" gate 403 will go high, and will be fed as an input into "and" gate 419, as stated above. The output of anticipation state "or" gate 403 is also provided as an input to "and" gates 413, 411, and 409. The other input to "and" gate 413 is the inverted OVERBLOWN signal. The other input to "and" gate 411 is the inverted UNDERBLOWN signal. The other input to "and" gate 409 is the TARGET signal. The outputs of "and" gates 409, 411, and 413 are provided to "or" gate 415. The output of "or" gate 415 is provided to inverter 417.

In operation, the detection of an overblown or underblown condition, or an indication that the extruded film tube is out of range of the sensor will cause the output of anticipation state "or" gate 403 to go high. This high output will be fed back through "and" gate 419 as an input to anticipation state "or" gate 403. Of course, the output of "and" gate 419 will be high for so long as neither input to "and" gate 419 is low. Of course, one input to "and" gate 419 is high because a change in the state of the OVER BLOWN signal, the UNDER BLOWN signal, and the TARGET signal has been detected. The other input to "and" gate 419 is controlled by the output of inverter 417, which is controlled by the output of next-state "or" gate 415. As stated above, the output of next-state "or" gate 415 is controlled by the output of "and" gates 409, 411, 413. In this configuration, anticipation state "or" gate 403 and "and" gate 419 are locked in a logic loop until a change is detected in a binary state of one of the following signals: the OVERBLOWN signal, the UNDERBLOWN signal, and the TARGET signal. A change in state of one of these signals causes

1 next-state "or" gate 415 to go high, which causes the output of inverter 417 to
2 go low, which causes the output of "and" gate 419 to go low.

3
4 The output of next-state "or" gate 415 is also provided to timer starter 421,
5 the reset pin for timer starter 421, and the input of block 423. When a high
6 signal is provided to the input of timer starter 421, a three second software
7 clock is initiated. At the beginning of the three second period, the output of
8 timer starter 421 goes from a normally high condition to a temporary low
9 condition; at the end of the three second software timer, the output of timer
0 starter 421 returns to its normally high condition. If any additional changes in
1 the state of the OVERBLOWN signal, the UNDERBLOWN signal, and the
2 TARGET signal are detected, the software timer is reset to zero, and begins
3 running again. The particular change in the input signal of the OVERBLOWN
4 signal, the UNDERBLOWN signal, and the TARGET signal, also causes the
5 transmission of a high output from "and" gates 409, 411, and 413 to blocks
6 429, 427, and 425 respectively.

7
8 In operation, when the input to block 423 goes high, the numeric value
9 associated with the variable identified as "quick filter align" will be pushed to a
0 memory variable identified as "speed hold". "Quick filter align" is a filter
1 variable which is used by software filter 149 (of Figure 23, which will be
2 discussed below), which determines the maximum allowable rate of change in
3 determining the estimated position. "Speed hold" is a holding variable which
4 holds the numeric value for the maximum allowable rate of change in
5 determining the estimated position of the blown film tube. "Speed hold" can
6 hold either a value identified as "quick filter align" or a value identified as
7 "normal filter align". "Normal filter align" is a variable that contains a numeric
8 value which determines the normal maximum amount of change allowed in
9 determining the estimated position of the blown film tube relative to the
0 transducer. Blocks 423 and 431 are both coupled to block 433 which is an

operational block representative of a "push" operation. Essentially, block 433 represents the activity of continuously and asynchronously pushing the value held in the variable "speed hold" to "LT2" in software filter 149 via data bus 402. The value for "normal filter align" is the same as that discussed herebelow in connection with Figure 8a, and comprises thirteen counts, wherein counts are normalized units established in terms of voltage. The preferred value for "quick filter align" is forty-eight counts. Therefore, when the software filter 149 is provided with the quick filter align value, the control system is able to change at a rate of approximately 3.7 times as fast as that during a "normal filter align" mode of operation.

Also, when a "locked" condition is obtained by anticipation state "or" gate 403 and "and" gate 419, any additional change in state of the values of any of the OVERBLOWN signal, the UNDERBLOWN signal, and the TARGET signal will cause "and" gates 409, 411, and 413 to selectively activate blocks 429, 427, 425. Blocks 429, 427, and 425 are coupled to block 433 which is linked by data bus 402 to software filter 149. When block 429 receives a high input, the variable held in the memory location "target restore count" is moved to a memory location identified as "align hold". When block 427 receives a high input signal, the value held in the memory location identified as "underblown count" is moved to a memory value identified as "align hold". When block 425 receives a high input signal, the numeric value held in a memory location identified as "overblown count" is moved to a memory location identified as "align hold". As stated above, block 433 performs a continuous asynchronous "push" operation, and will push any value identified to the "align hold" memory location to the values of SAMPLE (N), SAMPLE (N-1), and BPE in the software filter of Figure 23. In the preferred embodiment of the present invention, the value of "overblown count" is set to correspond to the distance between reference R and maximum circumference threshold B which is depicted in Figure 16, which is established distance at which the control system will

1 determine that an "overblown" condition exists. Also, in the preferred
2 embodiment of the present invention, the value of the "underblown" count will
3 be set to a minimum circumference threshold C, which is depicted in Figure 16,
4 and which corresponds to the detection of an underblown condition. Also, in
5 the present invention, the value of "target restore count" is preferably
6 established to correspond to the value of set point A, which is depicted in
7 Figure 16, and which corresponds generally to the distance between reference
8 R and the imaginary cylinder established by the position of the sizing cage with
9 respect to the blown film tube.

1 Figure 23A is a flowchart of the preferred filtering process applied to CURRENT
2 POSITION signal generated by the acoustic transducer. Preferably, it includes
3 multiple stages of filtering, for different operating conditions. The first stage of
4 filtering pertains to relatively unstable operating conditions. The second stage
5 of filtering pertains to relatively stable operating conditions. The digitized
6 CURRENT POSITION signal is provided from analog to digital converter 141 to
7 software filter 149. The program reads the CURRENT POSITION signal in step
8 161. Then, the software filter 149 sets SAMPLE (N) to the position signal.

1 In step 165, the absolute value of the difference between CURRENT POSITION
2 (SAMPLE (N)) and the previous sample (SAMPLE (N - 1)) is compared to a first
3 threshold. If the absolute value of the difference between the current sample
4 and the previous sample is less than first threshold T1, the value of SAMPLE
5 (N) is set to CFS, the current filtered sample, in step 167. If the absolute value
6 of the difference between the current sample and the previous sample exceeds
7 first threshold T1, in step 169, the CURRENT POSITION signal is disregarded,
8 and the previous position signal SAMPLE (N - 1) is substituted in its place.

9 Then, in step 171, the suggested change SC is calculated, by determining the
0 difference between the current filtered sample CFS and the best position

1 estimate BPE. In step 173, the suggested change SC which was calculated in
2 step 171 is compared to positive T2, which is the maximum limit on the rate of
3 change. If the suggested change is within the maximum limit allowed, in step
4 177, allowed change AC is set to the suggested change SC value. If, however,
5 in step 173, the suggested change exceeds the maximum limit allowed on the
6 rate of change, in step 175, the allowed change is set to +LT2, a default value
7 for allowed change.

8
9 In step 179, the suggested change SC is compared to the negative limit for
0 allowable rates of change, negative T2. If the suggested change SC is greater
1 than the maximum limit on negative change, in step 181, allowed change AC is
2 set to negative -LT2, a default value for negative change. However, if in step
3 179 it is determined that suggested change SC is within the maximum limit
4 allowed on negative change, in step 183, the allowed change AC is added to
5 the current best position estimate BPE, in step 183. Finally, in step 185, the
6 newly calculated best position estimate BPE is written to the PI loop program.

7
8 Software filter 149 is a two stage filter which first screens the CURRENT
9 POSITION signal by comparing the amount of change, either positive or
0 negative, to threshold T1. If the CURRENT POSITION signal, as compared to
1 the preceding position signal exceeds the threshold of T1, the current position
2 signal is discarded, and the previous position signal (SAMPLE (N - 1)) is used
3 instead. At the end of the first stage, in step 171, a suggested change SC
4 value is derived by subtracting the best position estimate BPE from the current
5 filtered sample CFS.

6
7 In the second stage of filtering, the suggested change SC value is compared to
8 positive and negative change thresholds (in steps 173 and 179). If the positive
9 or negative change thresholds are violated, the allowable change is set to a
0 preselected value, either +LT2, or -LT2. Of course, if the suggested change

1 SC is within the limits set by positive T2 and negative T2, then the allowable
2 change AC is set to the suggested change SC.

3
4 As is shown in Figure 23A, data bus 201 couples the emergency condition
5 control logic block 150 to software filter 149. As stated above, emergency
6 condition control logic block 150 is designed to asynchronously push a numeric
7 value identified in the memory location of "speed hold" to LT2 in software filter
8 149. Furthermore, emergency condition control logic block 150 will
9 asynchronously push a numeric value in the memory location identified as
0 "ALIGN HOLD" to SAMPLE (N), SAMPLE (N - 1), and BPE. As stated above,
1 SAMPLE N corresponds to the current position signal as detected by the
2 transducer. SAMPLE (N - 1) corresponds to the previous position signal as
3 determined by the transducer. BPE corresponds to the best position estimate.

4
5 Since the operation of emergency condition control mode logic block 150 is
6 asynchronous, block 186 of Figure 23A should be read and understood as
7 corresponding to an asynchronous read function. Therefore, at all times, as set
8 forth in block 186, software filter 149 receives values of "speed hold" and
9 "align hold" from emergency condition control mode logic block 150, and
0 immediately substitutes them into the various logic blocks found in software filter
1 149. For example, SAMPLE (N) is found in logic blocks 163, 165, and 167.
2 SAMPLE (N - 1) is found in logic blocks 165, and 169. BPE is found at logic
3 block 183. The program function represented by block 186 operates to
4 asynchronously and immediately push the values of "speed hold" and "align
5 hold" to these various functional blocks, since OVERBLOWN, UNDERBLOWN,
6 and lost TARGET conditions can occur at any time.

7
8 The normal operation of software filter 149 may also be understood with
9 reference to Figure 24, and will be contrasted with examples of the emergency
0 condition mode of operation as depicted in Figures 25, 26, and 27. In the

graph of Figure 24, the y-axis represents the signal level, and the x-axis represents time. The signal as sensed by acoustic transducer 79 is designated as input, and shown in the solid line. The operation of the first stage of the software filter 149 is depicted by the current filtered sample CFS, which is shown in the graph by cross-marks. As shown, the current filtered sample CFS operates to ignore large positive or negative changes in the position signal, and will only change when the position signal seems to have stabilized for a short interval. Therefore, when changes occur in the current filtered sample CFS, they occur in a plateau-like manner.

In stage two of the software filter 149, the current filtered sample CFS is compared to the best position estimate BPE, to derive a suggested change SC value. The suggested SC is then compared to positive and negative thresholds to calculate an allowable change AC which is then added to the best position estimate BPE. Figure 24 shows that the best position estimate BPE signal only gradually changes in response to an upward drift in the POSITION SIGNAL. The software filtering system 149 of the present invention renders the control apparatus relatively unaffected by random noise, but capable of tracking the more "gradual" changes in bubble position.

Experimentation has revealed that the software filtering system of the present invention operates best when the position of extruded film tube 81 is sampled between 20 to 30 times per second. At this sampling rate, one is less likely to incorrectly identify noise as a change in circumference of extruded film tube 81. The preferred sampling rate accounts for the common noise signals encountered in blown film extrusion liner.

Optional thresholds have also been derived through experimentation. In the first stage of filtering, threshold T1 is established as roughly one percent of the operating range of acoustic transducer 79, which in the preferred embodiment

1 is twenty-one meters (24 inches less 3 inches). In the second stage of filter,
2 thresholds +LT2 and -LT2 are established as roughly 0.30% of the operating
3 range of acoustic transducer 79.
4

5 Figure 25A is a graphic depiction of the control system response to the
6 detection of an UNDERBLOWN condition. The X-axis of the graph of Figure
7 25A is representative of time in seconds, and the Y-axis of the graph of Figure
8 25A is representative of position in units of voltage counts. A graph of the
9 best position estimate BPE is identified by dashed line 503. A graph of the
10 actual position of the extruded film tube with respect to the reference position
11 R is indicated by solid line 501. On this graph, line 505 is indicative of the
12 boundary established for determining whether the blown film tube is in an
13 "underblown" condition. Line 507 is provided as an indication of the normal
14 position of the blown film tube. Line 509 is provided to establish a boundary
15 for determining when a blown film tube is considered to be in an "overblown"
16 condition.
17

18 The activities represented in the graph of Figure 25A may be coordinated with
19 the graph of Figure 25B, which has an X-axis which is representative of time in
20 seconds, and a Y-axis which represents the binary condition of the TARGET
21 signal, and the UNDERBLOWN signal, as well as the output of block 421 of
22 Figure 22, which is representative of the output of the time out filter
23 realignment software clock. Now, with simultaneous reference to Figures 25A
24 and 25B, segment 511 of the best position estimate indicates that for some
25 reason the best position estimate generated by software filter 149 is lagging
26 substantially behind the actual position of the blown film tube. As shown in
27 Figure 25A, both the actual and estimated position of the blown film tube are in
28 an underblown condition, which is represented in the graph of Figure 25B.
29

30 As stated above, in connection with Figure 22 and the discussion of the

1 operation of the emergency condition control logic block 150, the locking
2 software loop which is established by anticipation state "or" gate 403 and
3 "and" gate 419 will lock the output of anticipation state "or" gate 403 to a
4 high condition. Therefore, next-state "or" gate 415 is awaiting the change in
5 condition of any of the following signals: the OVERBLOWN signal, the
6 UNDERBLOWN signal, and the TARGET signal. As shown in Figure 25A, at a
7 time of 6.5 seconds, the actual position of the blown film tube comes within
8 the boundary 505 established for the underblown condition, causing the output
9 of next-state "or" gate 415 to go high, which causes the output of inverter 417
0 to go low, which causes the output of "and" gate 419 to go low. This change
1 in state also starts the software timer of block 421, and causes block 427 to
2 push the value of "underblown count" to the "align hold" variable. Also,
3 simultaneously, software block 423 pushes the value of "quick filter align" to
4 the "speed hold" variable. The values of "speed hold" and "underblown count"
5 are automatically pushed to block 433. Meanwhile, the software timer of block
6 421 overrides the normal and continuous pushing of "normal filter align" to the
7 "speed hold" variable for a period three seconds. The three second period
8 expires at 9.5 seconds.

9
0 Thus, for the three second time interval 513, software filter 149 is allowed to
1 respond more rapidly to change than during normal operating conditions. As
2 shown in Figure 22, block 433 operates to automatically and asynchronously
3 push the value of "speed hold" to "LT2" in software filter 149.
4 Simultaneously, block 433 operates to continuously, automatically, and
5 asynchronously push the value of "align hold" to SAMPLE (N), SAMPLE (N-1)
6 and BPE in software filter 149. This overriding of the normal operation of
7 software filter 149 for a three second interval allows the software best position
8 estimate 503 to catch up with the actual position 501 of the blown film tube.
9 The jump represented by segment 515 in the best position estimate 503 of the
0 blown film tube is representative of the setting of SAMPLE (N), SAMPLE (N-1)

1 and BPE to the "underblown count" which is held in the "align hold" variable.
2 Segment 517 of the best position estimate 503 represents the more rapid rate
3 of change allowable during the three second interval, and depicts the best
4 position estimate line 503 tracking the actual position line 501 for a brief
5 interval. At the expiration of the three second interval, software filter 149 of
6 the control system returns to a normal mode of operation which does not allow
7 such rapid change in the best position estimate.

8
9 Figures 26A and 26b provide an alternative example of the operation of the
0 emergency condition control mode of operation of the present invention. In this
1 example, the TARGET signal represented in segment 525 of Figure 26b is
2 erroneously indicating that the blown film tube is out of range of the
3 transducer. Therefore, segment 529 of dashed line 527 indicates that the best
4 position estimate according to software filter 149 is set at a default constant
5 value indicative of the blown film tube being out of range of the transducer,
6 and is thus far from indicative of the actual position which is indicated by line
7 531. This condition may occur when the blown film tube is highly unstable so
8 that the interrogating pulses from the transducer are deflected, preventing
9 sensing of the blown film tube by the transducer. Segment 533 of Figure 26b
0 is representative of stabilization of the blown film tube and transition of the
1 TARGET signal from an "off" state to an "on" state. This transition triggers
2 initiation of the three second software timer which is depicted by segment 535.

3 The time period begins at 12.5 seconds and ends at 15.5 seconds. The
4 transition of the TARGET signal from a low to a high condition triggers the
5 pushing of the "target restore count" value to the "align hold" variable, as is
6 graphically depicted by segment 537. During the three second interval, the best
7 position estimate established by software filter 149 is allowed to change at a
8 rate which is established by the "quick filter align" value which is pushed to the
9 "speed hold" variable and bused to software filter 149. At the termination of
0 the three second interval, the software filter 149 returns to normal operation.

1
2 Figure 27A provides yet another example of the operation of the emergency
3 condition control mode. Segment 541 of Figure 27B indicates that the
4 TARGET signal is in a low condition, indicating that the blown film tube is out
5 of range of the transducer. Segment 543 indicates that the blown film tube
6 has come into range of the transducer, and the TARGET signal goes from a low
7 to a high condition. Simultaneous with the movement of the blown film tube
8 into range of the transducer, the UNDERBLOWN signal goes from a low to a
9 high condition indicating that the blown film tube is in an underblown condition.

0 Segment 545 of Figure 27B indicates a transition from a high UNDERBLOWN
1 signal to a low UNDERBLOWN signal, which indicates that the blown film tube
2 is no longer in an underblown condition. This transition initiates the three
3 second interval which allows for more rapid adjustment of the best position
4 estimate.

5
6 The foregoing description related to the first stage of filtering which is
7 especially useful during relatively unstable operating conditions, wherein
8 overblown and underblown extruded film tube conditions are possible. The
9 second stage of filtering, which will now be described, pertains to relatively
0 stable operating conditions, when the extruded film tube is in a substantially
1 fixed position. This type of filtering is preferably a dynamic filtering operation,
2 in which the influence of the dynamic filter is increased or decreased,
3 depending upon at least one pre-established criterion. Preferably, the criterion
4 comprises a comparison of the output of the filtering operation with the current
5 bubble position. If there is a great difference between the detected extruded
6 film tube position and the output of the filter, the operating assumption is that
7 the extruded film tube is perhaps becoming unstable, and the influence of the
8 dynamic filtering operation should be reduced. Conversely, if the difference
9 between the output of the dynamic filtering process and the current position of
0 the extruded film tube is small or decreasing, the assumption is made that the

1 extruded film tube is in a relatively stable operating condition, and the influence
2 of the dynamic filtering operation should be increased. In the present invention,
3 the dynamic filtering operation comprises a rolling average of detected position
4 signals, with the number of samples utilized to calculate the rolling average
5 increasing if stability is detected and decreasing if instability is detected. The
6 foregoing will become clear with reference to Figures 28A, 28B, 28C, 28D,
7 28E, 28F, and 28G.

8
9 With reference to Figure 23A, the basic filtering operation is depicted in
0 flowchart form. At the termination of software step 183, a best position
1 estimate (BPE) is calculated. The process continues at software block 184(a)
2 of Figure 23B, wherein the best position estimate is provided. Next, in
3 accordance with software block 184(b), it is determined whether or not an
4 alarm condition exists; if an alarm condition exists, the process continues at
5 software block 184(c), wherein the process continues by going to block 185 of
6 Figure 23A; if, however, it is determined in software block 184(b) that there is
7 no alarm condition, the process continues. In software block 184(d), the
8 processor determines whether or not the extruded film tube is in a startup
9 mode of operation; if so, the process continues at software block 184(e) by
0 passing control to software block 185 in Figure 23A; however, if it is
1 determined in software block 184(d) that the bubble is not a startup mode of
2 operation, the process continues. In software block 184(f), the controller
3 determines whether or not there is an ongoing change in extruded film tube
4 balance; if so, the process continues at software block 184(g) by passing
5 control to software block 185 in Figure 23A. However, if it is determined in
6 software block 184(f) that there is no ongoing change in extruded film tube
7 balance, the process continues. In accordance with software block 184(h), the
8 controller determines whether the extruded film tube (or "bubble") has been
9 stable for sixty continuous seconds; if not, the process continues at software
0 block 184(i), wherein control is passed to software block 185 in Figure 23A;

1 however, if it is determined in software block 184(h) that the bubble has been
2 stable for sixty continuous seconds, then control is passed to software block
3 184(j), wherein the dynamic filter of Figure 23C is utilized to process the
4 position signals during this relatively stable interval of operation.

5
6 In broad overview, the basic filtering operation of Figure 23A alone is
7 performed if any one of a variety of indicators reveal that stable operation is not
8 ongoing or is unlikely. A variety of the rudimentary indicators are identified in
9 Figure 23B, and various other indicators can be devised which can be added to
0 the items in Figure 23B which provide further screening which prevents the
1 dynamic filtering operation from commencing.

2
3 Once relatively stable operations are ongoing, the dynamic filtering operation
4 may be applied. The preferred embodiment of the dynamic filtering operation is
5 depicted in block diagram form in Figure 23C. As is shown, the process
6 continues at software block 184(k), wherein the best position estimate is
7 provided as an input to a rolling average generator 184(l) which computes a
8 rolling average from a number of previous samples of the best position estimate
9 (BPE), preferably based upon the following formula:

0
$$RA = RA + ((BPE - RA_{prev}) \div (Sample Number))$$

1 wherein

2 RA is the rolling average;

3 RA_{prev} is previous rolling average;

4 BPE is the best position estimate currently provided; and

5 Sample Number is a number which determines the number of samples
6 utilized to calculate the rolling average

7
8 The output of rolling average generator 184(l) is subtracted from the input to
9 the rolling average generator 184(l), which is the best position estimate (BPE).
0 This defines an "ERROR". This is provided as an input to the number of

1 samples calculator 184(m), which calculates the number of samples based
2 upon the ERROR (which is input), a predetermined GAIN value, and a BIAS
3 value in accordance with the following formula:

$$\text{SAMPLE NUMBER} = (\text{ERROR} \times \text{GAIN}) + \text{BIAS}$$

4
5
6 The BIAS 184(n) is a manufacturer-configurable variable which helps to
7 determine the span (or range) of available sample numbers utilized in
8 determining the rolling average. The output of the number of samples
9 calculator 184(m) is provided as an input to software block 184(o), which
0 pushes the Sample Number to the rolling average generator 184(l) every
1 second.

2
3 In accordance with present invention, the values for ERROR, GAIN and BIAS
4 are selected to insure that, during very stable operations, the rolling average
5 generator 184(l) utilizes ten (10) previous samples of the best position estimate
6 (BPE) in order to calculate the rolling average. If the difference between the
7 input to the rolling average generator 184(l) and the output of the rolling
8 average generator 184(l) increases, the number of samples calculator 184(m)
9 reduces the number of samples utilized by the rolling average generator 184(l).

0 When the difference (ERROR) is at its greatest (and most unacceptable) level,
1 the number of samples calculator 184(m) reduces the number of samples to
2 unity (1), therefore causing the input of the rolling average generator 184(l) to
3 be provided as the output of rolling average generator 184(l) without any
4 dynamic filtering whatsoever. In other words, as the ERROR increases, the
5 influence of the rolling average generator 184(l) is incrementally decreased from
6 its maximum influence to its minimum influence, which essentially bypasses the
7 dynamic filtering operation altogether.

8
9 As is shown in Figure 23C, the output of the rolling average generator 184(l) is
0 supplied to software block 184(p), which sets the BPE to the output of the

1 rolling average generator 184(l). Then, in accordance with 184(q), controls
2 return to software block 185 of Figure 23A.

3
4 The beneficial influence of the dynamic filtering operation can best be
5 understood with reference to Figures 23D and 23E. Figure 23D is a graphically
6 depiction of the bubble position 184(r) and the valve position 184(s) with
7 respect to time, without dynamic filtering. As is shown, the valve position
8 moves in direct correspondence with the bubble position, quite dynamically.
9 Figure 23E is a graphical depiction of bubble position 184(t) and the output of
0 the rolling average generator 184(u), as well as valve position 184(v), all with
1 respect to time. As is shown, the rolling average generator is much more
2 stable than the detected bubble position (BPE). The extreme positive and
3 negative peaks of the bubble position (BPE) are eliminated through the dynamic
4 filtering process, making the control system altogether less susceptible to noise
5 and meaningless bubble flutter than without the dynamic filtering process. As
6 is shown in Figure 23(E), the valve (or other flow control device) is basically
7 controlled by the output of the rolling average generator, and is also much less
8 susceptible to the noise or bubble flutter. This type of noise is a common
9 problem in particularly stiff materials, such as nylon.

0
1 Figure 23F is a graphical depiction of a frequency distribution comparison of the
2 dynamically filtered position signal shown in single cross-hatching and the
3 unfiltered position signal (BPE) shown in double cross-hatching. This frequency
4 distribution reveals that there is about a 33% reduction in the standard
5 deviation between the dynamically filtered position signal and the filtered, but
6 not dynamically filtered, position signal. In the real world, this relates to about
7 a 2 millimeter reduction in lay flat variation, which reduces a 6 millimeter total
8 variation to about a 4 millimeter total variation. This greatly increases the
9 control system's performance during these relatively stable operating intervals.

1 Figure 23G is a graphical depiction of startup operations with the dynamic filter
2 in place. The X-axis represents time and the Y-axis represents the valve
3 position 184(w), the bubble position 184(x), the output of the rolling average
4 generator 184(y). As is shown, the dynamic filtering operation is not active
5 until time 184(z), after which the prerequisite stability has been obtained. It is
6 at that point that the position of the valve 184(w) is directly controlled through
7 the rolling average generator. Note the greater stability of valve position once
8 the rolling average generator has been activated.

9
0 Figure 28 is a schematic and block diagram representation of an airflow circuit
1 for use in a blown film extrusion system. Input blower 613 is provided to
2 provide a supply of air which is routed into airflow circuit 611. The air is
3 received by conduit 615 and directed to airflow control device 617 of the
4 present invention. Airflow control device 617 operates as a substitute for a
5 conventional rotary-type airflow valve 631, which is depicted in simplified form
6 also in Figure 28. The preferred airflow control device 617 of the present
7 invention is employed to increase and decrease the flow of air to supply
8 distributor box 619 which provides an air supply to annular die 621 from which
9 blown film tube 623 extends upward. Air is removed from the interior of blown
0 film tube 623 by exhaust distributor box 625 which routes the air to conduit
1 627, and eventually to exhaust blower 629.

2
3 The preferred airflow control device 617 is depicted in fragmentary longitudinal
4 section view in Figure 29. As is shown, airflow control device 617 includes
5 housing 635 which defines inlet 637 and outlet 639 and airflow pathway 641
6 through housing 635. A plurality of selectively expandable flow restriction
7 members 671 are provided within housing 635 in airflow pathway 641. In the
8 view of Figure 29, selectively-expandable flow restriction members 673, 675,
9 677, 679, and 681 are depicted. Other selectively-expandable flow restriction
0 members are obscured in the view of Figure 29. Manifold 685 is provided to

1 route pressurized air to the interior of selectively-expandable flow restriction
2 members 671, and includes conduit 683 which couples to a plurality of hoses,
3 such as hoses 687, 689, 691, 693, 695 which are depicted in Figure 29 (other
4 hoses are obscured in Figure 29).

5
6 Each of the plurality of selectively-expandable flow restriction members
7 includes an inner air-tight bladder constructed of an expandable material such
8 as an elastomeric material. The expandable bladder is surrounded by an
9 expandable and contractible metal assembly. Preferably, each of the plurality
0 of selective-expandable flow restriction members is substantially oval in
1 cross-section view (such as the view of Figure 29), and traverse airflow
2 pathway 641 across the entire width of airflow pathway 641. Air flows over
3 and under each of the plurality of selectively-expandable airflow restriction
4 members, and each of them operates as an choke to increase and decrease the
5 flow of air through housing 635 as they are expanded and contracted.
6 However, the flow restriction is accomplished without creating turbulence in
7 the airflow, since the selectively-actuable flow restriction members are foil
8 shaped.

9
0 Returning now to Figure 28, airflow control device 617 is coupled to
1 proportional valve 657 which receives either a current or voltage control signal
2 and selectively vents pressurized fluid to airflow control device 617. In the
3 preferred embodiment, proportional valve 657 is manufactured by Proportion
4 Air of McCordsville, Indiana. Supply 651 provides a source of pressurized air
5 which is routed through pressure regulator 653 which maintains the pressurized
6 air at a constant 30 pounds per square inch of pressure. The regulated air is
7 directed through filter 655 to remove dust and other particulate matter, and
8 then through proportional valve 657 to airflow control device 617.

9
0 In the preferred embodiment of the present invention, airflow control device

1 617 is manufactured by Tek-Air Systems, Inc. of Danbury, Connecticut, and is
2 identified as a "Connor Model No. PRD Pneumavalve". This valve is the subject
3 matter of at least two U.S. patents, including U.S. Patent No. 3,011,518,
4 which issued in December of 1961 to Day et al., and U.S. Patent No.
5 3,593,645, which issued on July 20, 1971, to Day et al., which was assigned
6 to Connor Engineering Corporation of Danbury, Connecticut, and which is
7 entitled "Terminal Outlet for Air Distribution", both of which are incorporated
8 herein by reference as if fully set forth.

9
0 Experiments have revealed that this type of airflow control device provides for
1 greater control than can be provided by rotary type valve 631 (depicted in
2 Figure 28 for comparison purposes only), and is especially good at providing
3 control in mismatched load situations which would ordinarily be difficult to
4 control economically with a rotary type valve.

5
6 A number of airflow control devices like airflow control device 617 can be
7 easily coupled together in either series or parallel arrangement to control the
8 total volume of air provided to a blown film line or to allow economical load
9 matching. In Figure 28, a series and a parallel coupling of airflow control
0 devices is depicted in phantom, with airflow control devices 681, 683, and 685
1 coupled together with airflow control device 617. As shown in the detail
2 airflow control device 617 is in parallel with airflow control device 683 but is in
3 series communication with airflow control device 685. Airflow control device
4 685 is in parallel communication with airflow control device 681. Airflow
5 control devices 681 and 683 are in series communication.

6
7 The present invention is also directed to a method and apparatus for cooling
8 extruded film tubes, which utilizes a mass air flow sensor to provide a measure
9 of the flow of air in terms of both the air density and air flow rate. The mass
0 air flow sensor provides a numerical value which is indicative of the mass air

1 flow in an air flow path within a blown film extrusion system. A controller is
2 provided for receiving the measure of mass air flow from the mass air flow
3 sensor and for providing a control signal to an adjustable air flow attribute
4 modifier which serves to selectively modify the mass air flow in terms of mass
5 per unit time by typically changing one or more of the cooling air temperature,
6 the cooling air humidity, or the cooling air velocity. The preferred method and
7 apparatus for cooling extrude film tubes is depicted and described in detail in
8 Figures 30 through 36, and the accompanying text.

9
0 The particular type of mass air flow sensor utilized in the present invention
1 makes practical the utilization of mass air flow values in blown film extrusion
2 systems. Of course, "mass air flow" is simply the total density of the cooling
3 air or gas multiplied times the flow rate of the cooling air or gas. Typically,
4 blown film extrusion lines utilize ambient air for cooling and/or sizing the molten
5 blown film tube as it emerges from the annular die. It may become
6 economically practical in the future to utilize gases other than ambient air; for
7 purposes of clarity and simplicity, in this detailed description and the claims, the
8 term "air" is intended to comprehend both ambient air as well as specially
9 provided gases or gas mixtures.

0
1 While it is simple to state what the "mass air flow" represents, it is far more
2 difficult to calculate utilizing conventional techniques. This is true because of
3 the difficulty associated with calculating the density of air. Air which contains
4 water vapor requires the following information for the accurate calculation of
5 "mass air flow": the relative humidity of the air, the absolute pressure of the
6 air, the temperature of the air, the saturation vapor pressure for the air at the
7 given temperature, the partial pressure of the water vapor at the given
8 temperature, the specific gravity of the air, and the flow rate of the air.
9 Utilizing conventional sensors, one could easily measure relative humidity,
0 temperature of the air, absolute pressure, and the flow rate of the air. With

established data tables correlating the temperature of the gas and the relative humidity, the saturation vapor pressure and the partial pressure of the water vapor can be calculated. For ambient air applications, the specific gravity of the gas is unity so it drops out of consideration. A good overview of the complexity associated with the calculation of these factors which make up the "mass air flow" is provided in a book entitled *Fan Engineering: An Engineers Handbook On Fans And Their Applications*, edited by Robert Jorgensen, 8th edition, which is published by Buffalo Forge Company of Buffalo, New York. While such calculations are not particularly difficult given modern technologies for both sensors and data processors, the utilization of a single sensor which provides a direct indication of the "mass air flow" lessens the costs associated with implementation of the method and apparatus for cooling extruded film tubes of the present invention. Such use of a mass air flow sensor also reduces the complexity associated with calculating mass air flow utilizing a more conventional technique. This can be seen by comparing the calculations required for a system which does not utilize a mass air flow sensor, with one which does utilize a mass air flow sensor. The "mass flow rate" of air is determined by equation 1.1 which is set forth here below:

Equation 1.1

$$\text{Mass Flow Rate} = \text{Density} * \text{Flow Rate}$$

Of course, the flow rate is easy to obtain from flow rate meters, but the density of the cooling air must be determined in accordance with equation 1.2 which is set forth here below:

Equation 1.2

$$\text{Density} = ((P - P_{ws}(\phi)) + P_{ws}(\phi)(\omega)) / .7543 (T + 459.7)$$

wherein P is representative of the absolute pressure of the air, P_{ws} is representative of the saturation vapor pressure, ϕ is representative of the

relative humidity, and \bar{u} is representative of the ratio of the density of the water vapor to the density of dry air, and T is representative of the temperature of the cooling air in degrees F. Since we measure P, \bar{u} , and T directly, we only have to derive Pws and \bar{u} . By using a saturation vapor pressures table of water, we can determine the saturation vapor pressure (Pws) from the temperature of the cooling air. The following equation 1.3 allows one to calculate \bar{u} , which is the ratio of the water vapor density to dry air density:

Equation 1.3

$$\Omega = 1.6214 + ((\phi) * (Pws) \exp(1/1.42)) / 1130$$

This formula is accurate to 0.1% in the range of temperatures from 32°F to 400°F.

Therefore, it is evident that, in addition to a velocity sensor, sensors must be provided for the measurement of pressure, relative humidity, and temperature. Additionally, the saturation vapor pressure and the ratio of the density of water vapor to the density of dry air must be calculated utilizing a provided table, which in microprocessor implementations must be represented by a data array maintained in memory. All together, the complexity and opportunity for error presented by such an array of sensors and series of calculations and table look-up operations renders this technique difficult and expensive to implement.

In contrast, the present invention for cooling extruded tubes utilizes a single sensor which provides a direct measurement of the mass air flow. Such mass air flow sensors have found their principle application in internal combustion engines, and are described and claimed in the following issued United States Patents, each of which is incorporated herein by reference as if fully set forth:

- (1) U.S. Patent No. 4,366,704, to Sato et al., entitled Air Intake Apparatus For Internal Combustion Engine, which issued on January 4, 1983, and

- 1 which is owned by Hitachi, LTD., of Tokyo, Japan;
- 2 (2) U.S. Patent No. 4,517,837, to Oyama et al., entitled Air Flow Rate
- 3 Measuring Apparatus, which issued on May 21, 1985, and which is
- 4 owned by Hitachi, LTD., of Tokyo, Japan;
- 5 (3) U.S. Patent No. 5,048,327, to Atwood, entitled Mass Air Flow Meter,
- 6 which issued on September 17, 1991;
- 7 (4) U.S. Patent No. 5,179,858, to Atwood, entitled Mass Air Flow Meter
- 8 which issued on January 19, 1993.

9

0 Mass air flow sensors operate generally as follows. One or more (typically

1 platinum) resistor elements are provided in an air flow path way. An energizing

2 current is provided to the one or more resistor elements. Air passing over the

3 resistor elements reduces the temperature of the resistor elements. A control

4 circuit is provided which maintains currents at a constant amount in accordance

5 with King's Principal.

6

7 For the particular mass air flow sensor utilized in the preferred embodiment of

8 the present invention, the mass air flow of the air flowing through an air

9 pathway within a blown film extrusion system is established in accordance with

0 equation 1.4 as follows:

1 **Equation 1.4**

2
$$\text{Mass Flow Rate} = (\alpha)1.601 (\text{sensor reading} + \text{offset})^c$$

3 wherein the constants are attributable to the specific construction of the

4 sensor assembly.

5

6 In accordance with the present invention, a mass air flow sensor is utilized to

7 control air flow to cool molten polymers when extruded in a thin film tube. The

8 air flow may be provided in contact with either an interior surface of the thin

9 film tube, an exterior surface of the thin film tube, or both an interior surface of

0 the thin film tube and an exterior surface of the thin film tube. The air flow

1 amount must be consistent in order to maintain the desired cooling rate of the
2 polymer. Changes in the cooling rate modify the extent to which polymer
3 chains are formed, linked, and cross-linked. Under the prior art, the cooling air
4 is at best controlled to a constant temperature. There is no consideration in
5 prior art systems to the changes in the heat removing capacity of the air as the
6 air gets more or less humid, or as the absolute pressure changes. Changes in
7 the barometric pressure of one inch of mercury can change the mass air flow
8 rate by 3.3%. Changes in the temperature in the air typically have the greatest
9 effect on the heat removing capacity of the cooling air, with a 10% change in
0 relative humidity causing a tenth of 1% change in mass air flow rate. It is
1 estimated that utilization of the present invention in blown film extrusion lines
2 which have temperature control will add an additional accuracy in cooling up to
3 3.5%. For blown film extrusion lines which do not have temperature control,
4 the consistency in cooling can be improved by an amount estimated at 13% to
5 15% provided physical limits of the attribute modifying equipment are not
6 reached.

7
8 Cooling efficiency of course influences the production rate which can be
9 obtained blown film extrusion lines. Generally speaking, it is desirable to have
0 the extruded molten material change in state from a molten state to a solid
1 state before the blown film tube travels a predetermined distance from the
2 annular die. In the industry, the location of the state change is identified as the
3 "frost line" in a blown film tube. In the prior art, when big changes occur in the
4 temperature, humidity, or barometric pressure, the frost line of the extruded
5 film tube may move upward or downward relative to a desired location. This
6 may cause the operator of the blown film line to decrease production volumes
7 in order to keep from jeopardizing product quality, since product quality is in
8 part determined by the position or location of the frost line. While utilization of
9 the present invention improves the cooling of extruded film tubes, the present
0 invention also can be utilized to compensate for changes in the mass air flow

1 rate of the cooling gas supplied to the interior of a blown film tube and the hot
2 exhaust gas drawn from the blown film tube, to provide essentially a constant
3 frost line height, or at least a frost line height that does not move because of
4 changes in the mass air flow rate. Of course, the present invention can be
5 utilized in combination with prior art external cooling devices for blown film
6 extrusion lines to provide the same benefit.

7
8 So considered broadly, the present invention can be utilized to accomplish a
9 number of desirable results, including:

0 (1) it can be used as a frost line leveler for blown film extrusion line
1 with external air cooling only;

2 (2) it can be used in both the supply and exhaust systems of an
3 internal-bubble-cooling blown film extrusion system to manage and maintain a
4 balanced air flow between the supply and exhaust, which could greatly stabilize
5 the position of the frost line insofar as changes in the ambient temperature,
6 humidity, and barometric pressure effect the position of the frost line; this
7 could eliminate the need for prior art frost line location sensors;

8 (3) the mass air flow sensor can be utilized in combination with the
9 controller or computer to determine the most effective and efficient operating
0 range of flow pump devices such as blowers, and fans, by allowing the
1 computer to determine the mass air flow rate with relation to blower speed
2 (and valve position) and then systematically eliminate undesirable ranges of
3 operation, which are generally found at the lowest and highest ends of the
4 operating range, where the flow pump or valve may perform in a non-linear
5 fashion which would introduce unstable characteristics into the operation of the
6 blown film line;

7 (4) the mass air flow sensor can be utilized to provide a rather slow
8 feed back signal to a supply blower in the blown film line, to compensate for
9 changes in the ambient air, such as temperature, humidity, and barometric
0 pressure, which effect the mass air flow rate;

1 (5) the mass air flow sensor can be used to provide a feed back loop
2 which enhances the operation of a flow control valve in the line, to ensure that
3 the valve operation is providing a particular air flow characteristic in response to
4 a particular valve activation signal.
5

6 In the following detailed description, Figures 30 and 31 are directed to a blown
7 film extrusion system which includes an internal cooling air flow and an
8 external cooling air flow. In contrast, the detailed description relating to Figures
9 32 through 35 are directed to a more simple blown film extrusion system which
0 includes only an external cooling air flow.
1

2 With reference first to Figure 30, there is depicted an internal-bubble-cooling
3 blown film extrusion line 701 in schematic form. As is shown, blown film tube
4 703 is extruded from annular die 705. An ultrasonic transducer 707 is utilized
5 to gage the position of blown film tube 703, and provides a control signal to
6 position processor 709, all of which has been discussed in detail in this detailed
7 description. A sizing cage 711 is provided to size and stabilize the blown film
8 tube 703. A flow of internal cooling air is supplied to the interior of blown film
9 tube 703 through supply stack 713. As is conventional, exhaust stack 717 is
0 also provided in an interior position within blown film tube 703 for removing the
1 cooling air from the interior of blown film tube 703. A cooling air is supplied to
2 supply stack 713 through supply distributor box 715, and the exhausted air is
3 removed from blown film tube 703 through exhaust distributor box 719.
4 Additionally, an external cooling air ring 721 is provided for directing a cooling
5 stream of air to an exterior surface of blown film tube 703. Cooling air ring
6 721 collaborates with the internal cooling air stream to change the state of the
7 molten material from a molten state to a solid state. Cooling air ring 721 is
8 provided with entrained ambient air from air ring blower 723 which may be set
9 tot a flow rate either manually or automatically.
0

1 Supply distributor box 715 is provided with an entrained stream of cooling air in
2 the following manner. Ambient air is entrained by the operation of supply
3 blower 729. It is received at input filter 725, and passed through (optional)
4 manual damper 727. If supply blower 729 is a variable-speed-drive type of
5 supply blower, then manual damper 727 is not required. Preferably, however,
6 supply blower 729 is a variable speed drive controller which provides a selected
7 amount of air flow in response to a command received at a control input of
8 variable-speed-drive 731. Also, preferably, variable speed drive controller is
9 optionally subject to synchronous command signals from IBC controller 753
0 which controls the general operations of the blown film extrusion line. The
1 entrained ambient air is routed through air flow path 755, first through cooling
2 system 733, which preferably includes a plurality of heat exchange coils and
3 heat transference medium in communication with the air flow, which receives a
4 circulating heat exchange medium (such as chilled water for transferring heat),
5 past mass air flow sensor 737, through air flow control device 739 (such as
6 that depicted and described in connection with Figures 28 and 29 above), and
7 through supply distributor box 715. Mass air flow sensor 737 provides a
8 voltage signal which is indicative of the mass air flow of the air flowing through
9 air flow path 755 in the region between cooling system 733 and air flow
0 control device 739. Air flow control device 739 operates in response to
1 proportional valve 741 and selectively receives compressed air from
2 compressed air supply 743. Air flow control device 739 includes a plurality of
3 members which may be expanded and contracted to enlarge or reduce the air
4 flow path way through he housing of air flow control device. This allows for
5 the matching of loads, as is discussed above in connection with Figures 28 and
6 29. Proportional valve 741 is under the control of IBC controller 753.

7
8 Exhaust distributor box 719 removes cooling air from blown film tube 703 and
9 routes it through damper 745, into air flow path 755. The air passes through
0 mass air flow sensor 747 which provides a voltage which is indicative of the

1 mass air flow of the exhaust from blown film tube 703. The air is pulled from
2 air flow path 755 by the operation of exhaust blower 749 which is responsive
3 to an operator command, preferably through a variable speed drive 751, which
4 is also preferably under the synchronous control command of IBC controller
5 753.
6

7 In broad overview, mass air flow sensor 737 provides an indication of the mass
8 air flow of the cooling air which is supplied through supply distributor box 715
9 to supply stack 713. This cooling air removes heat from blown film tube 703,
0 helping it change from a molten state to a solid state. Mass air flow sensor
1 747 is in communication with the exhaust air removed through exhaust stack
2 717 and exhaust distributor box 719. Mass air flow sensor 747 provides a
3 voltage which is indicative of the mass air flow of the exhaust cooling air. The
4 measurements provided by mass air flow sensors 737,747 are supplied to a
5 controller which includes a microprocessor component for executing
6 preprogrammed instructions.
7

8 In accordance with the present invention, IBC controller 753 compares the
9 values from mass air flow sensors, 737, 747 and then provides command
0 controls to variable speed drives 731, 751 in order to effect the operation of
1 supply blower 729 and/or exhaust blower 749. Preferably, IBC controller 753
2 may be utilized in response to an operator command to maintain supply blower
3 729 and/or exhaust blower 749 at a particular level or magnitude of blower
4 operation, or to provide a particular ratio of blower operation, so that when the
5 temperature, humidity, or barometric pressure of the ambient air changes
6 significantly, the blowers adjust the flow rate of the input cooling air and
7 exhaust cooling air to blown film tube 703 to maintain uniformity of heat
8 absorbing capacity of the internal cooling air, notwithstanding the change in
9 temperature, humidity, and/or barometric pressure.
0

1 The operation of this rather simple feed back loop is set forth in flowchart form
2 in Figure 36. The process starts at software block 771, and continues at
3 software block 773, wherein IBC controller 753 receives an operator command
4 from either an operator interface 757 on IBC controller 753, or an operator
5 interface 759 on variable speed drive 731. Next, values provided by mass air
6 flow sensors 737 and 747 are recorded in memory, in accordance with
7 software block 775. Then in accordance with step 777, operation set points
8 are derived. For example, a particular ratio between the mass air flow detected
9 at mass air flow sensor 737 and mass air flow sensor 747 may be derived.
0 Then, in accordance with step 779, IBC controller 75 monitors signals from
1 mass air flow sensors 737 and 747 for changes in mass air flow, which are
2 principally due to changes in the ambient temperature, humidity, and barometric
3 pressure. Once a change is detected, in accordance with step 781 IBC
4 controller 753 synchronously adjusts the variable speed drives 759, 731, 751
5 in order to affect the value of the mass air flow of ambient air which has been
6 entrained and which is flowing through air flow passage way 755 in a manner
7 which returns operation to the set point values derived in step 777. For
8 example, variable speed drive 731, 751 may be utilized to increase or decrease
9 the volume of air entrained by supply blower 729 and/or exhausted by exhaust
0 blower 749. In accordance with step 783, this process is repeated until an
1 additional operator command is received. Such commands may include an
2 instruction to obtain a new operation set point, or to discontinue the feed back
3 loop until instructed otherwise. A cooling coil 738 may also be provided in
4 communication with air flow path 745, and may be adjusted in response to IBC
5 controller 753 to adjust the value of mass air flow.
6

7 Figure 31 depicts an alternative to the embodiment of Figure 30 wherein mass
8 air flow sensors are utilized to control both the internal cooling air supply to the
9 interior of blown film tube 703 and an external cooling air stream which is
0 supplied to the exterior surface of blown film tube 703 from air ring 721. The

1 figures differ in that, in addition of having a control system for internal cooling
2 air, a control system for external cooling air is also provided with a mass air
3 flow sensor 747 positioned in air flow path 741 between air ring blower 723
4 and cooling air ring 721. Mass air flow sensor 747 provides a measurement of
5 the mass air flow of the air flowing within air flow path 745. This
6 measurement is provided to IBC controller 753 and compared to a set point
7 value which has been either manually entered by the operator at operator
8 interface 757 or which has been automatically obtained in response to an
9 operator command made at operator interface 757. IBC controller 753 supplies
0 a control signal to variable speed drive 744 which is utilized to adjust the
1 operating condition of air ring blower either upward or downward in order to
2 maintain the established set point. If the mass air flow sensor 747 indicates to
3 IBC controller 753 that the total mass air flow has been diminished (perhaps
4 due to changes in temperature, humidity, and barometric pressure), then IBC
5 controller 753 may supply a command signal to variable speed drive 744 which
6 increases the throughput of air ring blower 723 in a manner which
7 compensates for the diminishment in mass air flow as detected by mass air
8 flow sensor 747. If mass air flow sensor 747 detects an increase in the mass
9 air flow, IBC controller 753 may provide a command signal to variable speed
0 drive 744 which increases the throughput of air ring blower 723 in a manner
1 which compensates for the diminishment in mass air flow a detected by mass
2 air flow sensor 747. If mass air flow sensor 747 detects an increase in the
3 mass air flow, IBC controller 753 may provide a command signal to variable
4 speed drive 744 which reduces the throughput of air ring blower 723, thus
5 diminishing the amount of mass air flow in order to make it equal to the set
6 point maintained in memory in response to an operator command. This simple
7 feedback loop is also characterized by the flowchart depiction in Figure 36.
8 Since changes in ambient temperature, ambient humidity, and barometric
9 pressure are rather slow, it is not necessary that this feedback loop be a very
0 fast loop. It is sufficient that every few minutes the value for the mass air flow

1 sensor be monitored to determine the numeric value of the mass air flow, that
2 this value be compared to a set point recorded in memory, and that an
3 appropriate command be provided to blower in order to adjust the mass air flow
4 upward or downward to make it equivalent to the set point value. This allows
5 a program which implement the present invention to be "piggy backed" onto
6 the IBC controller 753. The calculations required to compare mass air flow
7 values to set points is trivial and these operations need only be performed every
8 few minutes, so the IBC controller can spend the vast majority of its
9 computational power of controlling the blown film line, with only a de minimis
0 portion expended to occasional checking and adjusting of the mass air flow.
1 Additionally, a cooling coil 74 may be provided in communication with air flow
2 path 745, and may be provided in communication with air flow path 745, and
3 may be adjusted in response to IBC controller 753 to adjust the value of mass
4 air flow.

5
6 The present invention can also be utilized in far simpler blow film extrusion
7 systems which utilize only external cooling air to remove heat from a molten
8 blown film tube. Four particular embodiments are depicted in Figures 32, 33,
9 34, and 35. In each of these embodiments, a mass air flow sensor is
0 positioned intermediate and external cooling air ring and a blower for entraining
1 and supplying air to the cooling ring. Additionally an adjustable air flow
2 attribute modifier is provided in the air flow path for selectively modifying the
3 air mass per unit time. This adjustable air flow attribute modifier may comprise
4 any mechanism for adjusting for modifying the mass air flow, but in particular
5 will most probably comprise a cooling coil system which chills the cooling air,
6 or an air flow control device which restricts or enlarges the quantity of air
7 available for entrainment by the supply blower, or a fluid injection system
8 which modifies the humidity of the cooling air. Each of these three principle
9 alternative embodiments will be discussed in detail herebelow in connection
0 with Figures 32, 33, 34, and 35.

Turning first to Figure 32, an external cooling blown film extrusion line is depicted in schematic form. Plastic pellets are loaded into resin hopper 791, passed through heating apparatus 793, and driven by extruder 795 through die 797 to form a molten extruded film tube 789, with a portion of the extruded film tube 789 below frost line 801 being in a molten state, and that portion above frost line 801 being in a solid state. Air ring 799 is positioned adjacent die 797 and adapted to route cooling air along the exterior surface of blown film tube 789. Air ring 799 is supplied with cooling air which is entrained by air ring blower 803, routed through cooling coils 805 of cooling system 809, and through mass air flow sensor 807. Preferably, mass air flow sensor 807 is positioned in air flow path 821 intermediate cooling coils 805 and external cooling air ring 799. Cooling coils 805 are adapted to receive chilled water 813 from chiller system 811. Controller 815 is provided for receiving a signal from mass air flow sensor 807 which is indicative of the mass air flow of the cooling air flowing through air flow path 821, and for providing a command signal to chiller system 811 which adjusts the temperature of chilled water 813 which is routed through cooling coil 805. A feed back loop is established about a set point selected by the operator when a set point selection command button 817 is depressed. Controller 815 will respond to the command by recording in memory the mass air flow value provided by mass air flow sensor 807, and by adjusting the chiller system 811 upward or downward in temperature in order to maintain the mass air flow value of cooling air flowing through air flow path 821 at a value established by the set point. Of course, the operator has an operator interface for chiller system 811 which allows for the operator setting of the temperature of chiller system 811. This system works once the operator has established that sufficient cooling has been obtained, and should provide an equivalent level of cooling from the external cooling air provided by air ring 799 even though the ambient air changes its density through relatively slow changes in temperature, humidity, and barometric pressure. The embodiment

of Figure 32 is especially suited for blown film extrusion lines which have a dedicated chiller system. The embodiment of Figure 33 depicts a more common scenario, wherein a single chiller system is shared by multiple blown film lines. In this event, the configuration differs insofar as chiller system 811 is utilized to provide chilled water 813 for delivery to multiple heat exchange cooling coils, with a flow valve, such as flow valve 825, being provided of each set of heat exchange cooling coils to increase or decrease the flow of circulating heat exchange fluid in order to alter the temperature of the cooling air in air flow path 821. In the embodiment depicted in Figure 33, controller 815 provides an electrical command signal to an electrically-actuated flow valve 825 in order to increase or decrease the flow of chilled water 813 from chiller system 811 to cooling coil 805. Similar to the embodiment of Figure 32, the operator instructs controller 815 to record the mass air flow value from mass air flow sensor 807, and to utilize that as a set point for operation. Thereafter, changes in the mass air flow property of the cooling air passing through air flow path 821, such as changes caused by changes in temperature, humidity, and barometric pressure, are accommodated by increasing or diminishing the flow of chilled water from chiller system 811 to heat exchange cooling coil 805. Increases in mass air flow will result in the controller 815 providing a command to electrically-actuated flow valve 825 to diminish the flow of chilled water; in contrast, decreases in mass air flow as detected by mass air flow sensor 807 will result in controller 815 providing a command signal to electrically-actuated flow valve 825 to increase the flow of chilled water from chiller system 811 to heat exchange cooling coils 805.

Figure 34 is a schematic depiction of an external air blown film extrusion line, with blown film tube 789 extending upward from die 797 and being cooled by an air stream in contact with an exterior surface of blown film tube 789 which is provided by air flow path 821. Air flow path 821 includes mass air flow sensor 807 which provides a numerical indication of the mass air flow of the air

1 passing through air flow path 821. It provides this numerical indication to
2 controller 815, which in turn supplies a command signal to either variable speed
3 controller 831 or air flow control device 833 (such as that depicted in Figures
4 28 & 29 above), each of which can effect the volume of air which is entrained
5 by air ring blower 803. Controller 815 includes a manual control 817 which is
6 utilized by the operator to establish a set point of operation. Typically, the
7 operator will get the blown film line operating in an acceptable condition, and
8 then will actuate the set point command 817, causing controller 815 to record
9 in memory the value provided by mass air flow sensor 807. Thereafter,
0 changes in the mass air flow due to changes in temperature, humidity, or
1 barometric pressure will be compensated for by variation in the amount of air
2 entrained by air ring blower 803, in order to maintain mass air flow value at or
3 about the set point value. For example, if the mass air flow value decreases,
4 as determined by the mass air flow sensor 807, variable speed controller 831
5 or air flow control device 833 are provided with command signals from
6 controller 815 to increase the volume of air flowing through air flow path 821;
7 however, if the mass air flow value increases, as determined by mass air flow
8 sensor 807, controller 815 provides a command signal to either variable speed
9 controller 831 or air flow control device 833 in order to decrease the volume of
0 air entrained by air ring blower 803. In this manner, controller 815 may
1 intermittently check the value of the mass air flow, compare it to a set point
2 value recorded in memory, and adjust the volume of air entrained by air ring
3 blower 803 in order to maintain a mass air flow value at or about the set point.

4 In this manner, the cooling ability the air stream in contact with the exterior of
5 extruded film tube 789 is maintained at a constant level notwithstanding
6 gradual or dramatic changes in temperature, humidity, and barometric pressure.

7
8 Figure 35 depicts yet another embodiment of the invention, wherein an external
9 cooling blown film extrusion line is depicted in the schematic form, with
0 extruded film tube 789 extending upward from annular die 797, which is

1 cooled by an air stream provided by cooling air ring 799 Cooling air ring 799
2 receives its cooling air from air flow path 821. Mass air flow sensor 807 is
3 positioned in air flow path 821, and is adapted to provide a signal indicative of
4 the mass air flow of air flowing through this passage way, to controller 815.
5 Controller 815 provides a command signal to water injector 835 which is also
6 in communication with the air passing through air flow path 821. Water
7 injector 835 is adapted to increase the humidity of the air entrained by blower
8 803 in response to a command from controller 815. In accordance with this
9 embodiment of this invention, the operator depresses a set point control 817
0 on controller 815 in order to establish a set point o operation for controller 815.

1 Controller 815 records in memory the value of mass air flow sensor 807, and
2 thereafter continuously monitors the values provided by mass air flow sensor
3 807 in comparison to the set point. When an increase in mass air flow is
4 required, controller 815 provides a command signal to water injector 835 which
5 provides a predetermined amount of moisture which is immediately absorbed by
6 the air entrained by air ring blower 803. When no additional humidity is
7 required, controller 815 will no provide such a command. In this manner, the
8 mass air flow value for air entrained in air flow path 821 may be moderated by
9 operation of controller 815. Since this system easily allows an increase in the
0 mass air flow value, without allowing a corresponding decrease in the mass air
1 flow value, it is particularly useful in very hot and dry climates.

2
3 In all embodiments, it is advisable to provide a predetermined time interval of
4 time interval of monitoring before the set point is recorded and established.
5 This allows the operator to make changes in the operating condition of the
6 various blowers and other equipment in the blown film line prior to requesting
7 that a set point be established. It takes many minutes (5, 10, or 20 minutes) in
8 order for the system to reach a quiescent condition of operation. Having a
9 predefined interval of time after request for a set point, during which the mass
0 air flow values are monitored but not recorded, allows the operator to change

1 the operating state of the blown film line, and request a set point value, at the
2 same time, without obtaining a set point value which is perhaps not stable or
3 quiescent. In yet another more particular embodiment of the present invention,
4 the controller may be programmed to monitor the rate of change of the mass
5 air flow value for predetermined time interval in order to determine for itself
6 that a quiescent condition has been obtained. For example, a 10 or 20 minute
7 interval may be provided after operator request of a set point, during which the
8 controller continuously polls the mass air flow sensor, calculates a rate of
9 change for a finite time interval, and records it in memory. Only when the rate
0 of change reaches an acceptable level will the controller determine that a
1 quiescent interval has been obtained, and thereafter record the mass air flow
2 value in memory for utilization as a set point, or in the derivation of a set point,
3 about which the feedback loop is established.

4 **AUTOMATIC BLOWER BALANCING**

5
6
7 It is one objection of the present invention to provide a method and apparatus
8 for startup of an extruded film tube which includes a supply blower, an exhaust
9 blower, and a controller member, including executable program instructions
0 which define at least one control routine for automatic and coordinated control
1 of the supply blower and the exhaust blower during startup.

2
3 The control routines may comprise a startup routine which is utilized in initiating
4 the extruded film tube, a blower optimization routine which is utilized to
5 optimize the operating speeds of either or both of the supply blower and the
6 exhaust blower, and a valve optimization routine wherein an operating condition
7 is established for either or both of the supply blower and the exhaust blower in
8 a manner which optimizes operation of a valve member which is utilized to
9 control the application of air from the supply blower to the extruded film tube.
0

1 It is yet another objective of the present invention to utilize prior recorded
2 operating conditions for either or both of the supply blower and exhaust blower
3 in order to take advantage of the value of prior experience with a particular
4 blown film line.

5
6 It is yet another objective of the present invention to provide an additional
7 routine which can be utilized to detect bubble breaks during and after the
8 startup operations.

9
0 These and other objectives are achieved as is now described.

1
2 A method and apparatus is provided for startup of an extruded film tube. The
3 method and apparatus is used in a blown film extrusion apparatus in which film
4 is extruded as a tube from an annular die and pulled along a predetermined
5 path. A means is provided for varying a quantity of air within the extruded film
6 tube. Preferably, the means includes a supply blower which supplies air to the
7 extruded film tube in an amount corresponding to a supply control signal, and
8 an exhaust blower which exhausts air from the extruded film tube in an amount
9 corresponding to an exhaust control signal. A controller member is provided.
0 The controller member includes executable program instructions which define
1 at least one control routine for automatic and coordinated control of the means
2 for varying during startup of the extruded film tube. The controller directs a
3 series of supply control signals to the supply blower and exhaust control signals
4 to the exhaust blower in order to set their optimum operating conditions. In the
5 preferred embodiment, a control interface is provided for receiving operator
6 instructions during startup of the extruded film tube. The controller further
7 includes program instructions for receiving the operating instructions and
8 integrating the operating instructions into the at least one control routine. In
9 the preferred embodiment, a valve member is provided between the supply
0 blower and the extruded film tube. The valve member is under control of the

1 controller member, and is utilized for varying admission of air into the extruded
2 film tube and for controlling the circumference of the extruded film tube after
3 startup of the extruded film tube.

4
5 In the preferred embodiment, a variety of control routines may be provided. In
6 a startup routine, the controller member initiates operation of the supply blower
7 and the exhaust blower by first initiating operation of the supply blower in
8 accordance with at least one predetermined operating parameter, and then
9 initiating the exhaust blower in accordance with at least one predetermined
0 parameter.

1
2 In a blower optimization routine, at least one of the supply control signal and
3 the exhaust control signal is determined, at least in part, from at least one prior
4 recorded control signal. Preferably, a table is generated in controller memory
5 which records over time the optimum settings of the supply blower and
6 exhaust blower. During startup, the blower optimization routine may be utilized
7 to take advantage of the prior historical knowledge of the blown film apparatus.

8
9 In a valve optimization routine, an operating condition is established for at least
0 one of the supply blower and the exhaust blower in a manner which optimizes
1 operation of the valve member. In the preferred embodiment of the present
2 invention, the objective is to allow the valve member to operate in a preferred
3 and substantially linear range of closure conditions.

4
5 In a bubble break detection routine, a position signal (which indicates the
6 position or size of the bubble) is utilized in combination with at least one
7 software timer in order to detect a break in the extruded film tube. In the
8 preferred embodiment of the present invention, one software timer is utilized to
9 suppress operation of the bubble break detection routine until a portion of the
0 startup routine is completed. Then, a second software timer is utilized in order

1 to identify unacceptably long intervals of interruption in the position signal,
2 which is interpreted to identify a break or collapse of the extruded film tube.

3
4 Figure 37A is a pictorial and schematic representation of the prior art technique
5 for controlling an extruded film tube during startup operations. In the prior art,
6 a linear ratio controller is utilized by a human operator in order to determine and
7 set the balance condition of a supply blower and an exhaust blower in a blown
8 film extrusion apparatus. The prior art operates by utilizing human-set
9 potentiometers in order to balance the supply component 1003, load
0 component 1005, and the exhaust component 1007 in a linear ratio controller
1 1001. Determining the balance condition of a supply blower and an exhaust in
2 a blown film extrusion apparatus is complicated by the fact that the blowers
3 are non-linear. This is graphically depicted in Figures 37B and 37C. Figure 37B
4 is a graph 1009 of the response curve 1015 of a supply blower, with the X-
5 axis 1011 representative of the air flow in units of cubic feet per minute, and
6 the Y-axis 1013 representative of pressure in inches of water. As is shown in
7 Figure 37B, the response curve 1015 is not linear. Figure 37C is a graph 1017
8 of the response curve 1023 of an exhaust blower, with the X-axis 1019
9 representative of air flow in cubic feet per minute, and the Y-axis 1021
0 representative of pressure in inches of water. As is clear from Figure 37C, the
1 response curve 1023 of the exhaust blower is not linear.

2
3 Figure 37D is a schematic and block diagram representation of the startup
4 control apparatus 1030 of the present invention. As is shown, a die 1033
5 receives molten material and extrudes film tube 1031. Air is supplied to the
6 interior of extruded film tube 1031 via supply inlet 1035, and air is exhausted
7 from extruded film tube 1031 through exhaust outlet 137. During production
8 operations, a balance between the supply and exhaust must be maintained (in
9 fact, the balance is slightly biased toward supply) in order to maintain the
0 extruded film tube 1031 at a predetermined and substantially constant

circumference. As is shown in Figure 37D, supply blower 1037 communicates through air flow pathway 1036 to supply air to the interior of extruded film tube 1031. In accordance with the preferred embodiment of the present invention, valve member 1034 is provided within air flow pathway 1036 in order to provide for adjustment of the supply in order to allow for fine control over the circumference of the extruded film tube 1031, as has been discussed in detail above. Valve 1034 may comprise a rotary valve (as discussed above) or an air flow control member which includes selectively-expandable flow restriction members (also as discussed above). Exhaust blower 1039 communicates with the interior of extruded film tube 1031 through air flow pathway 1038. Supply blower 1037 and exhaust blower 1039 are under the control of variable speed drive 1041 and variable speed drive 1043 through control lines 1045, 1047. Supply control signals are directed to supply blower 1037 via control line 1045 to increase or decrease its output. Likewise, exhaust control signals are directed via exhaust control line 1047 to exhaust blower 1039 in order to increase or decrease its output. In accordance with the present invention, variable speed drives 1041, 1043 are under control of controller 1077.

Controller 1077 communicates with variable speed drive 1041 through stop/start line 1051 which stops/starts variable speed drive 1041, flow matching signal 1053 which communicates a control signal to variable speed drive 1041, actual speed line 1055 which provides an indication of the actual speed of supply blower 1037 to controller 1077, and OK switch 1049 which communicates through lines 1057, 1059 to controller 1077 which provides a signal to controller 1077 when variable speed drive 1041 is operating correctly.

Controller 1077 communicates with variable speed drive 1043 through stop/start line 1063 which provides a stop or start signal to variable speed drive 1043, actual speed line 1065 which provides an indication of the actual speed

1 of exhaust blower 1039 to controller 1077, and master IBC signal 1067 which
2 communicates through master speed reference 1071 (which is an operator-
3 adjustable potentiometer) which provides operator input to controller 1077
4 regarding the operating conditions of the supply blower 1077 and exhaust
5 blower 1039 during startup operations. Additionally, controller 1037 is
6 provided with a status indication via lines 1073, 1079 and switch 1061 which
7 provides an indication of the operating condition of variable speed drive 1043.
8

9 Controller 1077 communicates with control panel 1079 which provides data to
0 the operator, and which allows for operator input and commands. Control
1 panel 1079 includes inlet on/off switch 1083 and outlet on/out switch 1085
2 which allow the operator to stop and start the supply blower 1037 and exhaust
3 blower 1039. Preferably, control panel 1079 also includes manual blower input
4 means 1091 which allows for manual control of the blowers. Additionally,
5 control panel 1079 includes a blower balance display 1087 and master speed
6 display 1089. Preferably, and additionally, control panel 1079 includes
7 decrease button 1090, and increase button 1092, which allow the operator to
8 manually adjust either or both the supplier blower 1037 and exhaust blower
9 1039 during certain operations (but in the preferred embodiment, just the
0 supply blower), as will be discussed in detail below.
1

2 The startup control apparatus 1030 of the present invention allows the
3 operator to efficiently stabilize the extruded film tube by automatically
4 coordinating the flow rate of the supply blower 1045 with the flow rate of the
5 exhaust blower 1047. The startup control apparatus 1030 provides a special
6 startup feature that minimizes the need to establish a separate setup of startup
7 settings. Compensation for non-linear blower curves is managed by a
8 combination of learned settings and an efficient means to verify the learned
9 settings are still accurate. The startup control apparatus 1030 also includes a
0 bubble break detector that allows the option of stopping the production line

1 when a bubble break occurs. In accordance with the present invention, the
2 startup control apparatus 1030 monitors the status of each of the supply
3 blower 1045 and exhaust blower 1047 and uses such status to manage
4 startup and shutdown.

5
6 Figure 37E is a flowchart representation of some of the routines utilized during
7 startup procedures. The process begins at software block 1100 and continues
8 at software block 1101, wherein controller 1077 determines whether a startup
9 mode of operation has been selected; if so, control passes to software block
10 1103, wherein the startup procedure of Figure 37F(1) through 37F(2) is
11 performed. If it is determined in software 1101 that the startup mode has not
12 been selected, control passes to software block 1105, wherein controller 1077
13 determines whether the run mode has been selected; if the run mode has been
14 selected, control passes to software block 1107, where controller 1077
15 performs the run procedures of Figures 37G through 37J. If it is determined in
16 software block 1105 that the run mode has not been selected, control passes
17 to software block 1109, which determines whether the balance mode of
18 operation has been selected. If the balance mode of operation has been
19 selected, control passes to software block 1111, wherein controller 1077
20 performs the balance procedure of Figure 37K. If it is determined in software
21 block 1109 that the balance mode has not been selected, control passes to
22 software block 1113, where the process ends.

3
4 Turning now to Figures 37F(1) and 37F(2), the startup mode will be explained
5 with reference to the flowchart. The process begins at software block 1121
6 and continues at software block 1123, wherein the operator activates the inlet
7 blower. Next, in accordance with software block 1125, controller 1077
8 fetches a start percent parameter which is recorded in memory. In accordance
9 with the preferred embodiment of the present invention, the start percent
0 parameter is a predetermined percentage of the value of the master speed

control displayed on master speed display 1089 (of Figure 37D). In accordance with software block 1127, controller 1077 sends control signals through variable speed drive 1041 to supply blower 1037 in order to ramp supply blower 1037 up to the start percent parameter. In accordance with the present invention, a predetermined ramping function 1128 is stored in memory of controller 1077 which provides a bumpless ramp function which is followed in the ramping up of supply blower 1037. In the preferred embodiment of the present invention, the ramp function is non-linear to improve the blower response and to reduce the chance of overshooting the start percent value. An example of the ramp function 1128 is depicted adjacent software block 1127.

Next, in accordance with software block 1129, controller 1077 deactivates an outlet blower stop circuit in order to allow exhaust blower 1039 to start up. Next, in accordance with software blocks 1131 and 1133, controller 1077 determines whether the operator has adjusted the master speed reference potentiometer 1071 (of Figure 37D). If so, the inlet blower is adjusted in accordance with software block 1133. The process continues at software block 1135, wherein the operator determines that the extruded film tube (or "bubble") is through the roller nips (as is depicted in Figure 1). Next, in accordance with software block 1137, the operator activates the exhaust blower 1039 by actuating outlet on/off switch 1085. Next, in accordance with software block 1139, controller 1077 ramps the exhaust blower 1039 (through a predetermined ramping function 1140, which is preferably linear) to the full-rated value of the master speed reference potentiometer 1071 (of Figure 37D).

Controller 1077 then monitors the speeds of the supply blower 1037 and the exhaust blower 1039 in order to determine if the speeds are substantially equal, as set forth in software block 1141. If the speeds are not equal, monitoring and comparing operations continue. If it is determined in software block 1141 that the speeds of the supply blower and the exhaust blower are equal, control passes to software block 1143, wherein the inlet blower is

1 ramped (again, in accordance with a predetermined function 1144 which is
2 preferably non-linear) to the full-rated value of the master speed reference
3 potentiometer 1071 (of Figure 37D) as displayed on master speed display 1089
4 (also of Figure 37D). Next, in accordance with software block 1145, controller
5 1077 monitors the position of the extruded film tube. Next, and in accordance
6 with software block 1147, controller 1077 determines whether the extruded
7 film tube is within range of a predetermined sensor (preferably, the cage
8 sensor). If the extruded film tube is not within range, control passes back to
9 software block 1145; however, if the extruded film tube is within a
0 predetermined range, control passes to software block 1149, wherein controller
1 1077 is utilized to adjust the supply blower 1037 to place the valve 1036 in
2 the middle of its linear operating range.

3
4 In accordance with the present invention, valve 1036 may comprise either a
5 rotary valve or the "bladder" valve discussed above. Each of these valves has
6 a preferred and substantially linear operating range, but the valves are generally
7 not linear over their entire operating range. Therefore, in accordance with the
8 present invention, the linear operating range of a particular valve might be
9 determined empirically in a laboratory, and controller 1077 will be programmed
0 to maintain the valve in its relatively linear operating range. When a "bladder"
1 valve is utilized, that linear range represents a closure condition in the range of
2 28% to 32%. Operation outside of that narrow range of closure conditions
3 would be less than optimal. Since valve 1036 is utilized for fine control over
4 the circumference of the extruded film tube, it is relatively important that the
5 valve be operated over its optimal and linear range of operation. This will allow
6 for better control of the extruded film tube during production operations which
7 follow startup, and which have a significant impact on the product quality
8 produced by the blown film line and the product quantity produced by the
9 blown film line. Optimization of the valve will be discussed in greater detail
0 below. The process then ends at software block 1151.

1
2 The run mode of operation is depicted in flowchart form commencing at Figure
3 37G. The process commences in software block 1161, and continues at
4 software block 1163, wherein controller 1077 calls the blower balance routine
5 for execution. In broad overview, the controller 1077 works to balance the
6 supply and exhaust blowers 1037, 1039 by first looking for a recorded value
7 for the operating condition and associated supply blower setting from the last
8 time the system was running. In accordance with the present invention, a
9 plurality of values for prior production runs are stored in memory for use during
0 the run mode of operation. An array of such recorded historical run settings is
1 depicted in simplified form in Figure 37L. As is shown, three columns are
2 recorded, including the master speed potentiometer setting 1301, supply speed
3 1303, and reference volts 1305. For each master speed potentiometer setting
4 available, there is possibly a corresponding recorded historical value of supply
5 speed 1303 and its associated reference voltage 1305. Several dozen to
6 several hundred historical values may be recorded. These values represent prior
7 optimum settings of the supply blower 1037 for different operating conditions.
8 Since these particular settings were used in prior production runs, it is
9 presumed that they were satisfactory settings. In order to increase the
0 efficiency and accuracy of startup procedures, controller 1077 will first look to
1 historical and recorded values, if those values exist.

2
3 Returning now to Figure 37G, the process continues to software block 1165,
4 wherein controller 1077 determines whether a blower balance startup history
5 exists. In other words, controller 1077 determines whether there are any prior
6 historical and recorded values for the setting of supply blower 1037. If not,
7 control passes to software block 1167, and the process ends at software block
8 1169. However, if it is determined that a history does exist, control passes to
9 software block 1171, wherein controller 1077 examines the blower balancing
0 startup history to determine whether there is a value which has been recorded

1 for the current operating condition as set by the master speed potentiometer
2 setting. If no particular historical value corresponds to the current settings,
3 then control passes to software block 1173, and the process ends at software
4 block 1175. However, if it is determined that a prior recorded historical value
5 exists for the operating condition of the supply blower 1037, control passes to
6 software block 1177, and the process ends at software block 1179.

7
8 Figure 37H is a flowchart representation of software block 1167 of Figure 37G.

9 This routine is executed if a blower balance startup history exists. The
0 process being at software block 1201, and continues to software block 1203,
1 wherein controller 1077 examines the position of valve 1034 (of Figure 37D).
2 Next, in accordance with software block 1205, controller 1077 determines
3 whether valve 1034 is within its 28-32% state of closure. As discussed
4 above, this range represents the optimum and linear operating range of a
5 "bladder" valve which is described herein. If it is determined in software block
6 1205 by controller 1077 that valve 1034 is within its optimum range of
7 operation, the process ends at software block 1211. However, if it is
8 determined in software block 1205 that valve 1034 is not within its optimum
9 and linear operating range, the particular percentage of closure is examined to
0 determine whether it falls above or below the 28-32% range. If the closure
1 state is greater than 30%, control passes to software block 1027, wherein the
2 operating rate of supply blower 1037 is increased by a predetermined amount.
3 Control will then pass back to software block 1205 in order to reexamine the
4 operating condition of valve 1034. If it is determined at software block 1205
5 that valve 1034 is below 28% closure, control passes to software block 1209
6 wherein the rate of operation of supply blower 1037 is decreased by a
7 predetermined amount. Control would then return to software block 1205 in
8 order to allow for reexamination of the operating condition of valve 1034. This
9 process will repeat until valve 1034 is placed within its optimum and
0 substantially linear operating state.

1
2 Figure 37I is a flowchart representation of software block 1173 of Figure 37G.

3 This routine corresponds to a situation wherein a blower balance startup
4 history does exist, but no recorded and historical value exists which directly
5 corresponds to the current setting established for the blown film extrusion line.

6 The process begins at software block 1221, and continues at software block
7 1223, wherein controller 1077 fetches the operating speed for the supply
8 blower 1037 from a linear model. Function 1220 is a graphical representation
9 of such a linear model which maps values of the master speed potentiometer
0 setting to supply speeds (or the reference voltages which correspond to the
1 supply speeds). The model is a simple function ($y = mx$). The model value
2 which corresponds to the current speed potentiometer setting is then applied to
3 supply blower 1037. Next, in accordance with software block 1225, controller
4 1077 examines the position of valve 1034 to determine its current state.
5 Then, control passes to software block 1227, wherein controller 1077 is
6 utilized to determine whether valve 1034 is within its optimum and
7 substantially linear operating range of 28% to 32% (for the "bladder" type
8 valve discussed above). If the valve 1034 is operating within its optimum and
9 substantially linear operating range, control passes to software block 1233,
0 wherein the process ends. However, if it is determined in software block 1227
1 that valve 1034 is not within its preferred operating range, the closure state of
2 the valve is examined to determine whether it falls above or below the
3 preferred operating range. If the closure is greater than 32%, control passes to
4 software block 1229 wherein the operating condition of supply blower 1037 is
5 decreased by a non-linear offset component which is depicted by function
6 1222 (in the preferred embodiment, a predetermined constant is added to the
7 previous function in order to generate a function of $y = mx + b$). If it is
8 determined in software block 1229 that the valve is operating below the 28%
9 closure condition, control passes to software block 1231, wherein the
0 operation of supply blower 1037 is increased by a non-linear offset component

(in this situation, and in the preferred embodiment of the present invention, a constant term is added to the previous function in order to utilize a function of $y = mx - b$). This process is repeated until the valve 1034 is placed in its optimum range of operation.

Figure 37J is a flowchart representation of software block 1177 of Figure 37G.

In this situation, controller 1077 has determined that a blower balance startup history does exist, and that there is a value in the historical log which directly corresponds to the current master speed potentiometer setting. The process begins at software block 1241 and continues at software block 1243, wherein controller 1077 utilizes the last recorded value for the operating condition of supply blower 1037. Then, in accordance with software block 1245, the controller determines whether the extruded film tube (or "bubble") is at its proper size. Next, in accordance with software block 1247, controller 1077 determines whether the recorded value which is utilized for establishing the setting of supply blower 1037 places valve 1034 within its optimum range of operation (which, in the preferred embodiment for "bladder" type valves, is 28% to 32%). If it is determined in software 1247 that valve 1034 is not operating in its preferred range of positions, control passes to software block 1249, and the process ends at software block 1251. However, if it is determined in software block 1247 that the valve is indeed operating within its preferred range of positions, control passes to software block 1253, wherein the balance mode is not entered, and the process ends at software block 1255.

Figure 37K is a flowchart representation of software block 1249 of Figure 37J, and describes the balance mode of operation in accordance with the preferred embodiment of the present invention. The balance mode of operation is entered if the historical recorded value for the setting of supply blower 1037 does not place the valve in its preferred range of operation. The purpose of the balance mode of operation is to allow the operator to obtain direct control over

the operating condition of supply blower 1034. In the balance mode of operation, the position of valve 134 is locked to 30%. In control panel 1079, a ratio is displayed which represents the ratio of the running speeds of the supply blower 1037 and the exhaust blower 1039. An indication of 50% means that both blowers are running at the same speed. An indication greater than 50% means that the supply blower is running faster than the exhaust blower (which is the normal condition). An indication of less than 50% means that the supply blower is running slower than the exhaust blower. The operator can manually adjust the balance by using buttons **1097**, **1092** (of **Figure 37D**). Selecting the negative button will cause the supply blower to slow down.

With reference to **Figure 37K**, the process commences at software block **1261** and continues at software block **1263**, wherein controller **1077** locks the valve position to 30%. Next, in accordance with software block **1265**, control panel **1079** is utilized to display the "relative ratio" number. Then, in accordance with software block **1067**, controller **1077** monitors for operator input through depression of either the negative button **1090** or the positive button **1092**. In software block **1269**, controller **1077** monitors for selection of the negative button. If the negative button is selected, control passes to software block **1271**, wherein the supply blower is slowed down. In accordance with software block **1273**, controller **1077** monitors for selection of the positive button. If the positive button is selected, control passes to software block **1275**, wherein the supply blower is speeded up. In accordance with software block **1277**, controller **1077** monitors for selection of a production mode of operation by the operator. If the production mode is selected, in accordance with software block **1279**, controller **1077** records the setting in memory (in the table of **Figure 37L**) and the process ends at software block **1281**.

Figure 37M is a flowchart representation of a bubble break routine which is utilized after the initial steps of startup have been concluded in order to detect

1 bubble break or collapse, sound an alarm, and optionally shut down the blown
2 film line. The bubble break detection routine is suppressed during early phases
3 of the startup in order to allow the operator to get the bubble started. The
4 process commences at software block 1321, wherein the bubble break routine
5 is called for execution. Next, in accordance with software block 1323,
6 controller 1077 determines whether the blown film line is operational, and the
7 exhaust blower is in an on condition. In this way, the bubble break routine is
8 suppressed until the operator manually activates the exhaust blower. In
9 accordance with software block 1325, controller 1077 starts a timer delay
0 (which is operator-configurable in the range of 1-10 minutes) which allows an
1 amount of time sufficient for the operator to get the blown film line started. In
2 accordance with software block 1327, controller 1077 monitors the bubble
3 position sensor in order to determine the location of the bubble. In accordance
4 with software block 1329, the bubble position sensor is monitored to determine
5 whether there is a loss of signal. If no signal loss occurs, control returns to
6 software block 1327. However, if the position sensor signal is lost, control
7 passes to software block 1331, wherein a software timer is initiated. Then, in
8 accordance with software block 1333, controller 1077 determines whether the
9 signal is still gone. If not, control passes to software block 1327. If so, control
0 passes to software block 1339, wherein controller 1077 determines whether
1 the second software timer has "timed out". If not, control returns to software
2 block 1333; if so, control passes to software block 1337, where an alarm is
3 sounded. Alternatively, and concurrently with the sounding of the alarm, the
4 blown film line may be disabled. The routine ends at software block 1339. In
5 accordance with the present invention, controller 1077 is utilized to
6 continuously monitor the condition of the exhaust blower throughout the entire
7 process. Any change in condition of the exhaust blower will automatically
8 reset the bubble break detection routine to its initial condition. In this manner,
9 the bubble break routine will only run after the operator has been provided with
0 a sufficient time in which to get the extruded film tube within the nips, but only

1 becomes operational if the exhaust blower has been activated. Once the
2 position signal has been lost for a sufficiently long time interval, the bubble
3 break detector will at least sound an alarm in order to warn of likely break or
4 collapse of the bubble. Since the system automatically resets itself upon any
5 change in condition of the exhaust blower, it will become initialized for the next
6 startup.

8 LAYFLAT CONTROL

9
0 It is one objective of the present invention to provide a substantially improved
1 ability to keep blown film product width within established specifications. This
2 invention provides improved lay-flat control by adding a second feedback
3 control loop, in addition to, and in supplementation of, the primary control
4 feedback loop which is utilized to control the extrusion and cooling process.

5
6 This additional and supplemental control loop of the present invention measures
7 actual bubble diameter, preferably utilizing acoustic sensors, and feeds back
8 this information to one or more controllers. Preferably the controller is the one
9 which is utilized to perform the calculations and control operations of the
0 primary control loop for expanding and cooling the extruded film tube. The
1 sensed diameter data is compared against an operator established set point.
2 The resulting error is injected into the Internal Bubble Cooling system (the
3 "IBC") to provide a correction effect. In the preferred embodiment, this is in
4 fact directly added as an input to the primary control loop.

5
6 Preferably one or more non-contact acoustic sensors are located above the so-
7 called "frost line", thus providing a measure of the diameter of the product after
8 cooling but preferably BEFORE flattening of the extruded film tube by an
9 assembly of collapsing boards and nip rollers. In most conventional blown film
0 lines, this assembly is located overhead of the die and related components.

1 Thus the diameter sensors of the present invention are located above the
2 sensors of the primary control loop for controlling product diameter (through
3 control of the expansion and cooling of the extruded film tube) but beneath the
4 collapsing boards and nip rollers. This preferred placement of the second set of
5 bubble diameter measuring devices of the present invention above the IBC
6 sensors provides a quicker response than established methods in the prior art.

7
8 The prior art approach is characterized by the utilization of a lay-flat measuring
9 bar after the primary nip rollers. In the prior art systems, the distance between
0 the IBC sensors (of the primary control loop) and the lay-flat bar can be nearly
1 40 feet and when oscillating nip devices are used; of course, this path length of
2 the prior art approach can vary as the nip oscillates.

3
4 One additional problem of the prior art is resolved by the present invention. IBC
5 performance depends on stable airflow sources to maintain a stable bubble.
6 Therefore, disturbances can result in changes in the final product width. In
7 particular, rotating or oscillating dies use moving air chambers that can induce a
8 disturbance in the airflow as a result of uneven airflow in the chamber. In the
9 present invention, the variation in product diameter resulting from the airflow
0 changes that occur because of imbalances in the rotating chamber can be
1 significantly reduced.

2
3 In accordance with the preferred embodiment of the present invention, one or
4 more sensors are positioned in a different horizontal plane from the IBC control
5 sensors. Preferably, these sensors are also placed in a different circumferential
6 position than the primary control loop sensors. In this patent, these sensors are
7 called "lay-flat" sensors to distinguish them from the IBC sensors. In the
8 preferred embodiment, the placing the lay-flat sensors in a horizontal plane
9 vertically above the IBC sensors provides optimum results. The purpose of
0 these sensors is to provide a measurement of the actual bubble diameter from

1 which the final lay-flat dimension can be calculated from a simple formula (lay-
2 flat equals pi multiplied by the sensed diameter divided by two).
3

4
5 The preferred system of the present invention monitors the sensor(s) for proper
6 operation and selects which particular sensors are allowed to contribute to the
7 bubble diameter measurement. It also provides an indicator when all sensors are
8 not allowed to contribute. The system filters the received signal from one or more
9 sensors and calculates the expected lay-flat.
0

1 This system can also accept a calibration input from the operator. This
2 calibration input allows the operator to indicate the current actual lay-flat as
3 measured at the point of accumulation (such as a spooling system) for the
4 material. The system takes this reading and back calculates and adjustment
5 factor that accounts for the "draw down" of the material.
6

7
8 Draw down is the amount the material shrinks in width as a result of the
9 tension placed on the material during accumulation. The amount of draw down
0 is dependent upon both the material utilized in the extrusion line and the
1 amount of tension utilized in the accumulation operations. Thus the amount of
2 "draw down" is a function of both material and tension. The mixture and
3 composition of the material input into the blown film line is relatively fixed for
4 each product run; however, the material can vary greatly in composition (and
5 associated physical properties) between product runs. The amount of tension
6 applied to the accumulation or spooling system also varies between production
7 lines and production runs; however, the amount of tension applied is
8 susceptible to a greater amount or range of operator (and computer-system)
9 control.
0

1 Accordingly the lay-flat feature of the present invention is useful over a wide
2 variety of materials, which are used in blown film line, and it is also useful over
3 a wide range of production equipment.
4

5
6 In accordance with the preferred embodiment of the present invention, the
7 system converts the actual lay-flat signal into a signal that matches the signal
8 type used by the IBC sensor; in other words, the lay-flat signal can be
9 translated to the units and scale utilized by the primary control loop. The
0 system directly accepts as an input the converted lay-flat signal and compares
1 it to the operator-established set point.
2

3 The system also monitors the signal rate of change and position against
4 operator set windows of operation. This system essentially decides if the lay-
5 flat signal is stable and within acceptable range for proper corrective action. If
6 the signal is acceptable, the system applies an adjustable gain, inverts the
7 signal and injects the signal into the IBC control system.
8

9 The operation of the lay-flat control loop will now be described with reference
0 to Figures 38 and 39. Figure 38 is a flow chart representation of the overall
1 process of implementing the preferred lay-flat control loop in accordance with
2 the preferred embodiment of the present invention. The process is a
3 supplemental process to the primary IBC control loop. The computer
4 implemented steps are executed utilizing the processor which is utilized for the
5 IBC control loop. As is shown in Figure 38, the process begins at block 601. In
6 step 603, the processor determines whether or not there is an automated
7 measurement system for measuring the width of the final product as
8 accumulated or spooled. If such an automated system exists, then control
9 passes to block 605 wherein the width measure is read from the automated
0 system. If no such automated system exists, then control passes to block 607,
100

wherein the operator is prompted to enter the product width.

Once the product width information is obtained, in accordance with block 609, the measure is loaded in memory. Then in accordance with block 611, the lay-flat measurement system is activated to provide dynamic and real time information about the product diameter. In block 613, the controller determines whether or not the lay-flat sensors are in range. If the sensors are not in range, control passes to block 615 wherein the operator is prompted to reposition the acoustic sensors so that they are in range. After repositioning is confirmed in block 617, control passes to block 623; however, if repositioning is not confirmed, then the process ends in accordance with block 619 and a warning is given in accordance with block 621. Such warning can be a simple beeping sound or a blinking light, whatever is deemed sufficient to provide the operator with a warning.

Next in accord with block 623, the particular sensors which will be utilized are selected. Then in accordance with block 625, the processor monitors the output signals of all of the available sensors in order to determine which signals are the most stable and reliable. Signal rate of change is a good way to identify the best sensors, with high rates of change indicating a poor sensor. Next the most reliable signals are calibrated to match the scale of the signal provided to the control system by the IBC sensor. Then in accordance with block 629, the error signal developed by the lay-flat sensors are injected into the feedback loop in order to supplement the feed back loop of the IBC control loop.

Figure 39 depicts the process in a high level block diagram. IBC sensor monitors bubble position 707 and provides a feed back signal to controller 703. Controller 703 supplies a control signal to valve 705. This will have an impact on the bubble position 707. In accordance with the present invention, lay-flat sensor 711 monitors the diameter or width of the hardened product prior to collapsing and provides a similar input to controller 703. Together the feed back

1 signals from IBC sensor 701 and lay-flat sensor 711 allows better and more
2 timely control over the diameter of the finished product than can be
3 accomplished with the prior art approaches.

4 CAGE SIZE CONTROL

5
6
7 Figure 40 is a simplified pictorial representation of the present invention. As
8 is shown, lay flat sensors 801, 803 are fixed in position relative to the
9 extruded film tube 807, with a distance 805 therebetween which is known
0 and which is unchanged during the operations of the present invention. As
1 is shown in the view of Figure 40, the distance 805 is denoted as $d_{LF1-LF2}$.
2 Lay flat sensor 801 is an acoustic sensor which senses the distance d_{LF1}
3 between lay flat sensor 801 and the extruded tube 807. Lay flat sensor 803
4 is an acoustic sensor which measures the distance d_{LF2} between lay flat
5 sensor 803 and the extruded film tube 807.

6
7 Also, as is shown in this figure, a plurality of roller assemblies 813, 815 are
8 provided which surround extruded film tube 807. Figure 41 is a simplified
9 pictorial representation of the rollers. They comprise a number of individual
0 rollers which are coated in Teflon and which roll about a circular shaft. They
1 serve to engage the extruded film tube 807 when it is fully expanded and to
2 maintain its shape. Also, as is shown, a sizing cage 823 (which is shown in
3 extremely simplified form) is also provided in circumferential position relative to
4 extruded film tube 807. Sizing cage 823 may be moved inward and outward
5 relative to extruded film tube 807 by electrically-controllable actuator 819. The
6 actuator is a conventional element and may comprise a motor which may be
7 selectively energized to move the sizing cage 823 inward and outward relative
8 to extruded film tube 807. The IBC sensor 817 is secured in position relative to
9 sizing cage 823. The IBC distance 821 between the face of IBC sensor 817
0 and the inner surface of roller 815 is also known and fixed. Typically, this

1 distance, in accordance with the preferred embodiment of the present
2 invention, is seven inches.

3
4 The present invention utilizes IBC sensor 817 to measure the distance between
5 IBC sensor 817 and extruded film tube 807. It measures the sensor-to-bubble
6 distance 826. These measurements can be combined with the known distance
7 data for the location of the lay flat sensors 801, 803 and the location of the
8 IBC sensor 817 relative to cage 823 in order to determine the location of the
9 cage. This can be done without any prior knowledge of the actual location of
0 the cage. In the preferred embodiment of the present invention, it will be
1 useful to know the useful operating range of cage 823. This can be determined
2 by moving the cage to its maximum outer position and making a measurement,
3 and then moving the cage to its minimum inner position and making a
4 measurement. This establishes a useful range of control which also does not
5 require any prior knowledge and which can be determined utilizing the present
6 invention. An operator will have to determine, however, where these
7 maximum/minimum allowable positions actually are.

8
9
0 Figure 42 depicts in simplified form the distances known and measured which
1 are utilized in accordance with the present invention to calculate cage position.

2 It is important to note that the measurements must be consistent with respect
3 to whether the measurement is of diameter or circumference. Of course,
4 multiplying or dividing by pi can be utilized to normalize the data and make it
5 consistent. As can be seen from Figure 42, simple mathematic operations can
6 be utilized to calculate cage position. Cage position is derived by the
7 measurements obtained from the lay flat system plus the measurement of the
8 IBC sensor, plus the knowledge of the mounting distances for the lay flat
9 sensors and the IBC sensor. The mathematic operation is shown in simplified
0 form in the formula set forth in Figure 42.

1
2 In accordance with the preferred embodiment of the present invention, two
3 stages of control are utilized. One stage of control is known as a "forecast"
4 mode of operation. This mode of operation is utilized when there is a big
5 difference between the actual cage position and the desired cage position as
6 determined by input from the operator in the form of a cage position setting.
7 The other mode of operation is considered a "contact" mode of operation in
8 which the actual cage position is very close to the desired cage position as
9 determined by the setting recorded from the operator input.
0

1 In broad overview, during the "forecast" mode of operation, the lay flat system
2 is manipulated by the cage control software to inject error correction signals
3 into the IBC control loop. The lay flat control system allows for much more
4 aggressive or rapid changes either in enlarging the bubble or reducing the
5 bubble. The present invention makes use of this fact and "tricks" the lay flat
6 control system into acting as if the product being produced is out of
7 specification (i.e., either too broad or too narrow) and thus allows the lay flat
8 control system to essentially override the IBC control system for brief intervals
9 in order to size the bubble up or down quite rapidly.
0

1 In accordance with the preferred embodiment of the present invention, the
2 "forecast" mode of operation is accomplished by stepping the lay flat control
3 through a series of changes that are within a predefined amount of the useful
4 operating range of the lay flat control system. For example, the lay flat control
5 system typically operates plus or minus 4" from a particular product
6 specification set point. Accordingly, in the preferred embodiment of the
7 present invention, the lay flat control system is moved through a series of steps
8 of approximately 2." Really, the steps are between 1" and 2", but for purposes
9 of discussion, 2" will be utilized. For example, if the operator desires to change
0 the cage position from 60" in diameter to 80" in diameter, the preferred cage

control system of the present invention will step the lay flat control system through a series of corrections, approximately 2" at a time. Accordingly, ten different "steps" will be utilized to allow the lay flat system to inject correction signals to the IBC control system.

Once the actual cage position is within a predetermined range, control will pass to a "contact" mode of operation which allows for finer adjustments to be made. This stands in sharp contrast with the gross or large adjustments which can be made utilizing the lay flat control system.

Figure 43 is a simplified flowchart representation of the present invention and will be utilized to further illustrate the "forecast" and "contact" modes of operation. This will be followed by a detailed discussion of the flowcharts for the code. Bear in mind that the flowchart of Figure 43 is a flowchart of the concepts. The process begins at block 901, and continues at block 903, wherein the lay flat sensors are utilized to measure the finished product at that particular time. In accordance with step 905, the IBC sensor is utilized to measure the sensor-to-bubble distance. Then, in accordance with step 907, the controller is utilized to calculate actual cage position. Then, in accordance with step 909, a comparison is made between the actual cage position and the operator setting for the cage position. If there is a change or difference in the cage position from the set point, as determined by step 911, control passes to block 913. If there is no change or difference, control returns to block 903. In accordance with block 913, the controller determines how big the change is. If the change is "big" the control passes to block 915. If the change is "small" control passes to block 917. In accordance with block 915, the controller breaks the difference between the actual cage position and the operator setting into a number of units which are serially utilized to allow the lay flat control system to inject correction signals into the IBC control system, thus essentially overriding the IBC control system and accelerating the expansion or reduction

1 of the bubble as the cage is rapidly enlarged or reduced in diameter. In
2 accordance with block 921, this process is iteratively performed until the last
3 step is identified. In accordance with block 923, the last step is identified and
4 control passes to block 917. However, if the last step has not been identified,
5 the iterative processing continues.

6
7 During this processing, the lay flat control system is intentionally supplied with
8 an inaccurate measure of the product dimension. This causes an aggressive
9 reaction by the lay flat control system to override the IBC control system and
0 enlarge or reduce the bubble. In fact, the data supplied to the lay flat control
1 system is merely a form of manipulation and does not reflect an accurate
2 measure of the completed product. If it is determined in step 913 that the
3 change is small, control passes to block 917, wherein the contact mode of
4 operation is entered. The contact mode of operation is characterized by a
5 cessation of the manipulation of the lay flat control system so it is no longer
6 manipulated to introduce correction signals into the IBC control loop.
7 Therefore, accurate lay flat data is provided. However, the contact mode of
8 operation allows the operator to introduce slight overage or underage values to
9 the bubble in order to slightly move the cage inward and outward to over or
0 under "squeeze" the bubble.

1
2 Figures 44A through 44T are flowchart representations of one preferred
3 implementation of the present invention in order to obtain control over cage
4 size in order to allow the automatic sizing of a cage in response to operator
5 input. This is accomplished utilizing the IBC control system, blower balance
6 system, and lay flat control system as described below. At various portions of
7 operation, these systems are utilized in a manner to accomplish the goals of
8 controlling the cage. It is important to note that the code which is represented
9 by these flow charts is run on a PID loop controller which is relatively
0 rudimentary compared to microprocessors utilized in other types of equipment,

such as personal computers. One that is skilled in the art of PID loop programming will recognize that many of the functions are especially tailored to accommodate the execution of this code by the PID loop controller. Utilizing a more powerful, higher-level processor would likely simplify programming. Commencing with Figure 44A, there is depicted a flowchart of a routine which runs only when echo loss occurs. "Echo loss" is the loss of a return or "echo" signal from the IBC controller. This may represent a collapse or rupture of the bubble, but is more likely to represent some momentary loss of measurement due to ambient noise, flutter of the bubble, or many other factors which do not correspond to the rupture of loss of the bubble. In other words, loss of a signal does not equate to loss of a bubble. The routine of Figure 44A depicts the preferred response to the loss of signal from the IBC controller. The flowchart begins at block 1001 which identifies this as part of a main processing loop. This means that the functions performed by the flowchart of Figure 44A are of the highest priority and are operated on the highest polling speeds. This is important because the loss of a signal could correspond to the loss of a bubble and one would want appropriate rapid response to such a condition. In accordance with block 1003, the controller determines whether the echo has been lost. If it has been lost, control passes to block 1005. If it has not been lost, control passes to block 1009. In accordance with block 1005, the controller determines whether the echo has been recovered. In other words, has there been a recent previous loss of signal. If no, control passes to block 1017. However, if a recent previous loss of echo has occurred, the controller identifies the situation as being one in which there has been a echo "recovery."

Accordingly, control will pass to block 1007 which calls an echo re-started routine which is depicted in Figure 44Q and which will be discussed later below. Essentially, the program requires a certain interval of stability after any particular loss of echo before conducting control operations in an ordinary manner. In other words, a certain amount of caution is utilized once there has been a loss of signal. The program is designed to provide an indicator of this

condition in the form of the setting of various flags. The exact amount of the stable interval of operation required before this cautious mode of control is terminated is a matter of design choice and may be set to meet particular engineering objectives. In the view of Figure 44A, once the routine identified with block 1007, and depicted in Figure 44Q, has been performed, control returns to block 1017. If it is determined in block 1005 that the echo is not a recovered echo, control passes to block 1017.

If it is determined in block 1003 that the echo has been lost, control passes to block 1009, wherein an echo flag is examined to determine whether it is on. If it is determined to be on in block 1009, control passes to block 1011 in which the controller determines whether the cage controller is currently operating. If it is determined in block 1011 that the cage controller is not operating, control passes to block 1017. If it is determined in block 1011, that the cage controller is indeed operating, control passes to block 1013. Block 1013 calls a pause cage controller routine. Once the pause cage controller routine is executed, control passes to block 1015 which turns off the echo flag, then control passes to block 1017. The flowchart of Figure 44A depicts the situation which assumes that there has been a change requested by the operator in the cage size.

Figure 44B is a flowchart representation of a routine which corresponds to a timed interrupt which takes the form of external code which is not executed in the PID loop. In this particular embodiment, the cage is checked at a defined interval. In this example, the interval is every 1.5 seconds. The process commences at block 1019 which represents entry of the check cage mode of operation. Control passes to block 1021 in which the controller checks to determine if the cage controller is running or operating. If it is operating, control passes to block 1023; if it is not operating, control passes to block 1027, which is a return command. If the cage controller is running or operating, in

1 accordance with step 1023, the controller determines if the cage control
2 system has been running at least two execution cycles of the PID loop. In
3 accordance with the preferred embodiment of the present, in a "forecast" mode
4 of operation, the PID loop is executing approximately every five seconds. In
5 contrast, in a "contact" mode of operation, the PID loop is executing every
6 fifteen seconds. Accordingly, checking for the operating condition of the cage
7 control routine every 1.5 seconds is adequate provided that a sufficient amount
8 of processing time is allowed to pass. This corresponds to the cycle
9 requirements of block 1023. If the PID loop has been operating or running for
0 the required execution time or intervals, control passes to block 1025. If it has
1 not been running, the designated execution cycles or time control passes to
2 block 1027. In accordance with block 1025, the controller calls the cage mode
3 controller routine which will be discussed below.

4
5 Figure 44C is a flowchart representation of the cage mode controller. This is a
6 main routine which is broken onto several sheets. In fact, this routine is
7 depicted on three sheets, namely Figures 44C, 44D, and 44E. The logical
8 connection between these pages in the flowchart are designated by the letters
9 "A" and "B." The process commences at block 1029 upon entry of this cage
0 mode controller module. Control passes to block 1031 in which the controller
1 determines whether the cage control mode of operation is an available function.
2 If the cage controller mode of operation is not an available function, control
3 passes to block 1033 in which the stop controller routine is called for
4 execution, followed by a passing of control to block 1035 which is a return
5 block. However, if it is determined in block 1031 that the cage control module
6 is available, control passes to block 1037. In block 1037, the controller
7 determines whether the bubble is "oversized." If it is determined in block 1037
8 that the bubble is oversized, control passes to block 1043 in which it is
9 determined whether the cage is "closing." If the cage is closing, control passes
0 to block 1039 which calls the pause controller routine for execution. In

1 practical terms, a bubble is likely to be determined to be "oversized" if the cage
2 is being closed. Accordingly, the controller would want to pause the cage
3 controller routine until the bubble is finished closing. After execution of the
4 pause controller routine as mandated by block 1039, control passes to
5 block 1041 which is a return block. If it is determined in block 1037 that the
6 bubble is not oversized, control passes to block 1045 in which the controller
7 determines whether the cage control system is currently running. If the cage
8 control system is not current running, control passes to block 1047 which calls
9 the restart controller routine, and passes control to block 1049 which is a
0 return. If it is determined in block 1045 that the controller is currently running,
1 control passes to block 1051. In block 1051, the controller determines
2 whether the cage position is within a defined dead band.

3
4 It is determined in step 1051 that the cage position is not within the dead
5 band, control passes to the loop defined by blocks 1053, 1055 and 1057. In
6 block 1053, a count down counter "T" is examined to determine if it is greater
7 than 1. Essentially, the count down counter counts the number of PID loop
8 executions which are necessary to enlarge or reduce the cage size by an
9 amount which corresponds to the steps in which the difference is segmented or
0 divided. As discussed above, these steps are typically less than 2" and
1 correspond to a fractional portion of the plus or minus 4" range of operation
2 which typically which is a good operating range for the lay flat controller. In
3 accordance with block 1053, the content of the count down counter "T" is
4 examined and compared to determine whether it is greater than 1. If it is not
5 greater than 1, this indicates that the system is stable since it is able to quickly
6 span the distance of the step and get into the "dead band" which is the outer
7 extent of the step. In that case, control passes to block 1055 which is a
8 return. If in block 1053 it is determined that the count down counter "T" is
9 indeed greater than 1, control passes to block 1057 which decrements the
0 counter and passes control to block 1055.

1
2 In accordance with the flow of Figure 44C, if it is determined in block 1051
3 that the cage position is within the dead band, control passes to block 1059
4 which determines whether both blowers are on. If in block 1059 it is
5 determined that both blowers are not on, control passes to block 1061 which is
6 a return. If it is determined in block 1059 that both blowers are on, control
7 passes to block 1063. Block 1063 is representative of the controller
8 determining whether to enter the "forecast" mode of operation (which is
9 represented by the connector "B") or the "contact" mode of operation (which is
0 represented by the connector "A").

1
2 Figure 44D depicts the "contact" mode of operation, while Figure 44E depicts
3 the "forecast" mode of operation.

4
5 Turning first to the forecast mode operation of Figure 44E, control passes to
6 block 1081 in which the controller calculates the difference between the
7 operator set point and the cage position or "set point." Control then passes to
8 block 1083 in which the controller determines whether all the steps have been
9 completed. If the steps have been completed, control passes to block 1084 in
0 which the stability counter "T" is incremented by the addition of 1. Then
1 control passes to block 1085 which determines whether the processing has
2 completed at least a filter sample (which in the current embodiment is at least
3 five seconds of processing). If the processing has been completed for at least
4 the filter sample, control passes to block 1087 which calls for the "contact"
5 mode of operation. Then control passes to block 1089 which is a return. If it
6 is determined in response to block 1085 that the processing has not been
7 completed for at least the filter samples, block 1087 is bypassed and control
8 passes to block 1089.

9
0 In block 1083, the controller determines whether the steps have been

1 completed. If the steps have not been completed, control passes to block
2 1091. In block 1091, the controller determines whether the set point is within
3 one-half the distance of the lay flat controller window. In the commercial
4 embodiment, this corresponds to whether the set point is within 2" of the
5 operator set point. In other words, is the cage position located within one step
6 interval (approximately less than 2")? If the cage position is less than one step
7 away from the operator selected set point, control passes to block 1093 which
8 represents a "jump" in which the cage set point is set to the operator set point.
9 In other words, no further processing is required. Then control passes to block
0 1095 which is a return. However, if it is determined in block 1091 that the set
1 point is not within one "step" of distance from the operator set point, control
2 passes to block 1095 in which the cage controller set point is moved by one-
3 half of one lay flat controller window step toward the operator set point. In
4 other words, block 1095 mandates the taking of a "half" step. Then, in
5 accordance with block 1097, a delay timer is set or "stuffed" with a
6 predetermined delay. This timer value must be sufficient to ensure the loop
7 executes at least once before checks are made. Control then passes to block
8 1099.

9
0 Figure 44D is a flowchart representation of the "contact" mode of operation.
1 The processing commences at block 1065 in which the controller determines
2 whether the lay flat controller is within its "tolerance." If not, control passes to
3 block 1067 in which the stability counter "T" is examined in order to determine
4 whether it is greater than 1. If it is greater than 1, control passes to block 1069
5 in which the stability counter "T" is decremented by 1 and control is passed to
6 block 1020. If it is determined in block 1019 that the stability counter is not
7 greater than 1, control passes to block 1071. If it is determined in block 1065
8 that the lay flat controller is indeed within tolerance, the stability counter "T" is
9 incremented by 1 in accordance with block 1073. Then control passes to block
0 1075 in which the controller determines whether the process has been stable

1 for at least five PID loop executions. If the controller determines that such
2 stability exists, control passes to block 1079 in which a call is made to the stop
3 contact mode. Then control passes to block 1077 which is returned. However,
4 if it is determined in block 1075 that the stability has not been maintained for
5 at least five PID loop executions, control passes to block 1077 which is return.
6

7 In practical terms, during the contact mode of operation, the controller expects
8 to see extremely stable conditions for bubble position. If the lay flat condition
9 is not within tolerance, that is determined to be an unstable condition and the
0 stability counter is decremented, but only if it is greater than 1. If the lay flat is
1 operating within tolerance, the stability counter is incremented and a timed
2 interval is determined for stable operations before the contact mode is
3 terminated. It is the dual satisfaction of the tolerance and stability
4 requirements which result in termination of the contact mode of operation. This
5 signifies that the bubble has reached a stable position with the cage located in
6 the new position as mandated by the operator input of the position set point.
7

8 Figure 44F will now be discussed. Figure 44F is related to the echo loss and
9 restore routines. Therefore, it is related to the routines depicted in Figures 44P
0 through 44T.
1

2 In accordance with Figure 44F, the low speed routine commences at block
3 1101 and continues at block 1103 in which the low speed filter constants are
4 loaded into the IBC system. These "filter constants" determine an operating
5 state for the IBC bubble monitoring and control system which provide a less
6 rigorous amount of control. Then control passes to block 1105 in which the
7 echo flag is set on the cage controller. In accordance with block 1107,
8 housekeeping functions are performed by clearing a low speed delay timer and
9 setting the value of a coil which is a PID loop programming system for
0 recording a state. This flowchart corresponds to the operation of the cage
113

1 control system when a previous recent loss of echo has occurred so the system
2 is operating in an echo restore mode of operation.
3

4 Figures 44P through 44T will now be discussed as they relate to the lost echo
5 and echo restore modes of operation. Turning first to Figure 44P, the echo lost
6 process commences at block 1245. In accordance with block 1247, the EC
7 flag is set to zero. This indicates to the system that the echo has been lost.
8 As stated above, this corresponds to either the mere loss of a signal or some
9 problem with the bubble such as a rupture or some other loss of control. In
0 accordance with block 1249, the echo hold flag is set to zero. This indicates to
1 the controller that the controller should be in a hold mode of operation. In
2 accordance with block 1251, the current position is saved to memory. This
3 allows the system to "snap" back to the last good measure of current position
4 in the event that the echo is regained. As stated above in considerable detail,
5 the last good measure of position is sometimes the entry point for a return of
6 control after some perceived or possible loss of control event occurs. In
7 accordance with block 1253, a preprogrammed delay is started before the echo
8 hold finishes. In other words, a timer is set which must expire before the echo
9 hold will be released. Control then passes to block 1255 which is a return.

1 Figure 44Q depicts an echo restored module which commences at block 1257.
2 Control passes to block 1259 in which the EC flag is set to 1. This represents
3 a presence of echo or return of echo. In accordance with block 1261, the echo
4 hold flag is set to 1. This indicates a suspension or release of the echo hold
5 mode of operation. Then, in accordance with block 1263, the controller
6 rechecks for alarm statuses. In other words, the controller checks to determine
7 whether there is some other alarm condition is occurring. Then, in accordance
8 with block 1265, the controller rechecks the fill alarm system. This represents
9 a checking by the controller to determine whether the bubble is in a
0 "undersized" condition.

1
2 This flowchart continues on Figure 44R. Next, the controller determines
3 whether the system is in a "manual mode" of operation in accordance with
4 block 1267. If so, control passes to block 1269 in which the loop alarms are
5 cleared. However, if the controller determines that the system is not in a mode
6 of operation, control passes to block 1271 in which a flag is set on the cage
7 controller. This represents an echo flag. Then, in accordance with block 1273,
8 the controller calls a restart cage controller routine which is depicted in Figure
9 44K in which will be discussed below. Then, in accordance with block 1275,
0 the controller determines whether the hold has expired. If the hold has expired,
1 control passes to block 1277, in which the position recorded in memory prior to
2 the loss of signal is pushed or set as the current bubble position. If the hold is
3 not expired, in accordance with block 1275, control passes to block 1281 in
4 which the timer is cleared and the flag is held, then control passes to block
5 1283 which is a return. If the hold is expired, and the bubble position is set to
6 the last recorded bubble position, then in accordance with block 1279, the
7 controller calls a high speed filter routine. This high speed routine does not
8 perform as much filtering as a low speed filter routine, so there is less delay
9 associated with this high speed routine. This is useful in recovering from loss of
0 echo situations in which speed is more important than accuracy of the
1 measurements which can be achieved through a high degree of filtering.
2

3 Figure 44S depicts a high speed mode of operation after the echo hold expires.
4 The process commences at block 1285 and continues at block 1287 wherein
5 the timer has expired so the echo hold flag is set to 1 which indicates such
6 expiration. Then control passes to 1289 which calls a high speed routine. This
7 lets the IBC control system perform in an ordinary manner to control the bubble
8 in accordance with its control routines. Then, in accordance with block 1291,
9 the hold expire coil is reset, which is a form of housekeeping in order to record
0 the state. Then control passes to block 1293 which is a return.

1
2 Figure 44T is a high speed routine which commences at block 1295. In
3 accordance with the high speed routine, the controller utilized the save position
4 and utilizes it to "seed" the filtering system. Then, in accordance with block
5 1299, the high speed filter constants are loaded by the controller into the IBC
6 filter system. Next, in accordance with block 1301, the echo flag is set off for
7 the cage controller. In accordance with block 1303, the controller determines
8 whether the echo is still lost. If so, control passes to block 1307 which is
9 returned. If not, control passes to block 1305 which starts a delay to low
0 speed filtering.

1
2 Figures 44G and 44H depict routines associated with the manual opening and
3 closing of a cage by an operator. In typical blown film lines, the manual control
4 of the cage size is accomplished through the pressing and releasing of a control
5 switch or switch system. The "pressing" of the controls represents a manual
6 control. A "release" of the control represents a return to automated control.
7 With reference first to Figure 44G, the open cage routine 1111 is depicted. In
8 accordance with block 1113, the controller determines whether the manual
9 control has been "pressed" or "released." Pressing indicates the exercise of
0 manual control by the operator over the cage positioning system. Control
1 passes to block 1115 in which the pause cage control routine is called for
2 execution. Then, in accordance with block 1117 the controller forms a
3 housekeeping function to indicate that manual control had been exercised. In
4 accordance with block 1119, the cage is then opened in response to the
5 manual control, and control returns in accordance with block 1121. Upon
6 release, as determined by block 1113, control passes to block 1123 in which
7 the cage output is set to zero. Next, in accordance with block 1125, the
8 controller stops any opening of the cage. Then, in accordance with block
9 1127, the controller calls the restart cage controller routine in accordance with
0 block 1127. Then control passes to the return of block 1129.

1
2 Figure 44H depicts the manual closing of the cage by the operator. Once
3 again, this routine will only run when the operator uses manual cage controls.
4 A "pressing" indicates that the manual exercise is controlled by the operator.
5 The "release" indicates the return to automated control over the cage size. The
6 process commences at block 1131, and continues at block 1133, wherein the
7 controller determines whether a pressing or releasing has occurred. If a
8 pressing has occurred, control passes to block 1143 in which the cage
9 controller is paused. Then, control passes to block 1145 in which
0 housekeeping functions are performed to record that manual control has been
1 exercised. Then, in accordance with block 1147, the cage is closed in
2 response to the continuing "pressing" by the operator of the control systems.
3 Then control passes to block 1149 which is a return. The controller detects
4 the release at block 1133 and then sets the cage output to zero in accordance
5 with block 1135. Then it stops closing the cage in accordance with block
6 1137. Next, in accordance with block 1139 it calls the restart cage controller
7 routine. Then control passes to block 1141 which is a return.

8
9 Figure 44I is a flowchart representation of a routine for stopping the cage
0 controller. The process commences at block 1143 and continues at block
1 1145 in which the cage controller flag is turned "off." This indicates an "off"
2 condition for the cage controller which may be differentiated from a pause
3 condition. The pause controller command of block 1149 and the stop control
4 command have similar impacts but one results in the setting of a flag
5 corresponding to the cage controller being stopped, while the pausing operation
6 does not set such a flag. In either event, control passes to block 1147 in
7 which the cage controller is put in a manual mode of operation. The output is
8 cleared and the outputs are turned off. Control then passes to block 1151
9 which determines whether the cage controller is in a forecast mode of
0 operation. If so, passes to block 1153 in which the stability counter T is set to

1 zero and certain other housekeeping functions are performed. Control passes
2 from blocks 1151 and 1153 to block 1155 which is a return.

3
4 Figure 44J is a flowchart representation of a module for starting the forecast
5 mode of operation. The process commences at block 1157 and continues at
6 block 1159 in which the controller determines whether the cage control system
7 is available. If not, control passes to block 1161 which is a return. If so,
8 control passes to block 1163 in which the stability counter T is set to zero and
9 the forecasting flag is turned "on" indicating an initiation of the forecast mode
0 of operation. Then, control passes to block 1165 in which the initial position is
1 set to a set point which ensures a "bumpless" PID input. Control passes to
2 block 1165 which is a return. The routine of Figure 44J is a dependent routine
3 from Figure 44M which will be discussed below. It represents a "smooth start"
4 operation.

5
6 Figure 44K is a flowchart representation of a free start operation which
7 commences at block 1169 and continues at block 1171 in which the controller
8 determines whether the cage control system is active. If the cage control
9 system is determined in block 1171 to be active, control passes to block 1173
0 which puts the controller in an auto mode. If it is determined in block 1171
1 that the controller is not active, control passes to block 1175 which sets the
2 way to ensure one execution of the PID loop before further testing. Then
3 control passes to block 1177.

4
5 Figure 44L is a depiction of a module for starting the "contact" mode of
6 operation which commences at block 1179. Control passes to block 1181 in
7 which the controller determines whether the cage control function is available.
8 If it is not available, control passes to block 1183 which is a return. If it is
9 available, control passes to block 1185 in which the cage set point is set to
0 equal the operator set point. In other words, the position of the cage and the

operator selected position for the cage are set to be equal. Additionally, the deadband is then set in order to accommodate the repidity of response (or agility) of this particular extrusion line. In accordance with block 1187, a operating flag is set to a "on" condition in order to indicate the starting of the contact mode of operation. Control then passes to block 1189 which is a return.

Figure 44M depicts the routine known as process lay flat of block 1191. In accordance with block 1193, the controller determines whether the set point has changed. If not, control passes to block 1205 in which the controller is utilized to calculate a new lay flat in accordance with normal lay flat operation. If however, the controller determines in block 1193 that a new set point has been selected by the operator, control passes to block 1195 in which the controller calculates the difference between the old set point and the new set point. This is important to determine whether control should pass directly to the "contact" mode of operation for relatively minor differences or to a "forecast" mode of operation to allow the lay flat controller to be actively involved and aggressively moving cage position through several steps to a new enlarged or reduced position. Control then passes to block 1197 in which the controller examines the difference to determine whether it is greater than one-half of the lay flat control window. If, for example, the lay flat control window is 4", the controller would determine whether the difference is greater than 2".

If the difference is not greater than 2", block 1199 is bypassed and control passes to block 1201 in which the new set point is stored in memory. Therefore, situations in which a relatively small difference exists between the old position set point for the cage and the new operator-selected set point, and the system will automatically set cage position to the new value without perturbing other system such as the lay flat control system or the blower balance system. However, if it is determined in block 1197 that the difference is greater than one-half the lay flat control window, control passes to block

1 1199 in which the automatic blower balance system is started. This will allow
2 the automatic blower balance system to cooperate with the cage control
3 system and the lay flat control system in order to reposition the cage to a new
4 radially expanded or radially reduced size in response to the operator-selected
5 new set point or position value for the cage. In accordance with block 401, the
6 set point is changed. Then, in accordance with block 1203, the controller
7 restarts the cage controller, and passes control to block 1205. This flow chart
8 continues on the next page in Figure 44N. Before continuing, it is important to
9 note that in accordance with block 1199, the system is automatically sent into
0 an unbalanced condition on purpose. This is done in order to allow the blower
1 balance system to allow more rapid changes of the valves which control the
2 airflows in the exterior and interior portions of the blown film tube. As may be
3 recalled from earlier discussion, the blower balance system maintains the valves
4 operating in a substantially linear portion which provides very good control and
5 allows for quick responses both in opening and closing of the valve. An
6 initiation of an automatic blower balance routine will allow for relatively rapid
7 changes in the valve position as part of the overall accommodation of the new
8 cage size settings as determined by the operator-input set point. In other
9 words, a temporary out of balance condition is created intensely by the
0 controller through the initiation or starting of the automatic blower balance
1 system in order to facilitate changes in the cage size.

2
3 The discussion will continue now with reference to Figure 44N. As is shown,
4 in accordance with block 1207, the controller determines whether the cage
5 controller is active. If so, control passes to block 1209 in which the controller
6 calculates deviations based upon the cage set point. If not, control passes to
7 block 1211 in which the controller calculates deviations based upon the lay flat
8 set point. In other words, at this point, the lay flat control system is utilized to
9 manipulate the blown film line and to inject correction signals which have
0 nothing whatsoever to do with the lay flat dimension of the product being out

1 of specification, but which have everything to do with a calculated
2 manipulation of the lay flat system in order to aggressively move the cage
3 between a preexisting condition and an operator desired, and new cage
4 position. This occurs at block 1213 in which the controller calculates a rate of
5 change in the lay flat based upon the substituted (erroneous) lay flat
6 measurements provided by the controller to the lay flat module. In accordance
7 with block 1215, the controller then calculates the lay flat controller response.
8 This corresponds to the amount of the correction signal which is injected into
9 the IBC system in order to correct for out of specification products.
0

1 The process continues on Figure 440. In accordance with block 1217, the
2 controller determines whether the cage controller is active. If not, control
3 passes to block 1243 which is an end point. If so, control passes to block
4 1219 in which the controller determines whether the system is in a "forecast
5 mode." If not, control passes to block 1222 in which the cage controller is
6 updated with a new lay flat. If it is determined in block 1219 that the system
7 is in the forecast mode, control passes to block 1223 in which the controller
8 determine whether the IBC sensor is in good operating condition. If so, control
9 passes to block 1233. If not, control passes to block 1225 which examines to
0 determine whether the stability counter "T" is greater than zero. If not, control
1 passes to block 1227 in which the IBC unstable flag is set to zero and the
2 stability counter "T" is set to zero. If it is determined in block 1225 that the
3 stability counter is greater than zero, control passes to block 1229 in which the
4 stability counter is reduced by one.
5

6 If it is determined that the IBC sensor is in good condition in accordance with
7 block 1223, control passes to block 1233 in which the controller determines
8 whether the stability count is less than the stability threshold. If so, control
9 passes to block 1231 in which the stability counter is incremented by one. If
0 not, control passes to block 1235 which the stability counter is examined to